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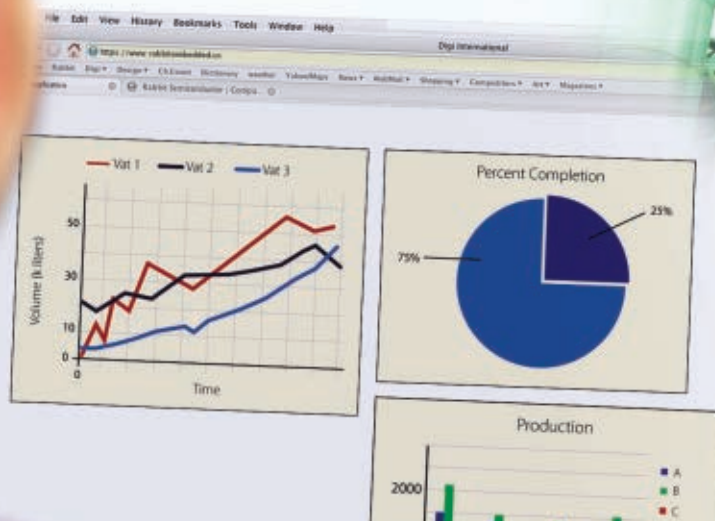
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A photograph of a musician, Pete Lewis, performing on stage. He is wearing a white shirt and light-colored pants, and is playing a guitar. A microphone is positioned in front of him. In the background, another musician is visible, playing a guitar. The stage is lit with warm, yellow and orange lights.

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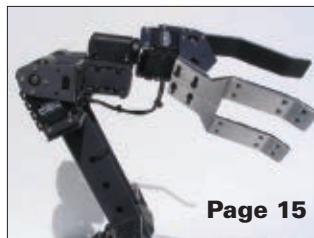
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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Clean Power

While clean power is frequently equated with green power, it can also refer to AC power free from spikes,

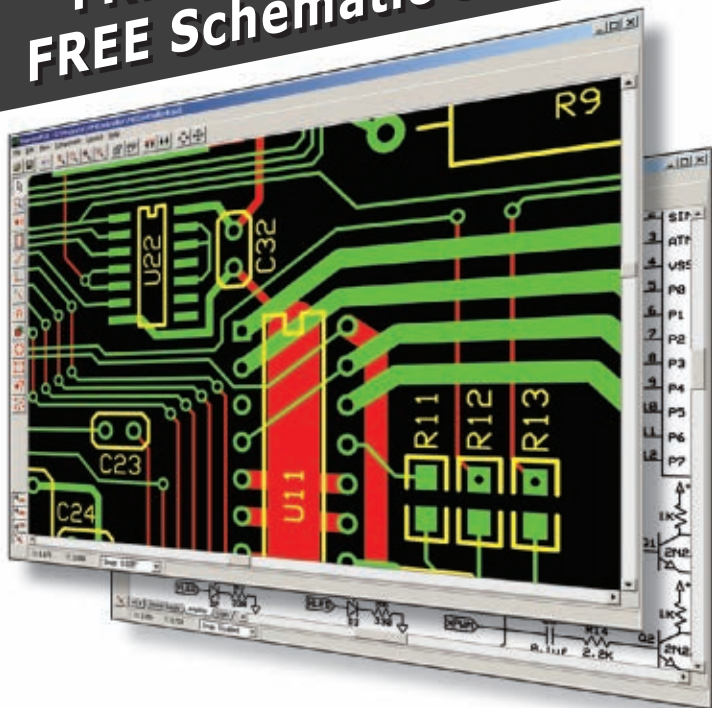
dips, surges, audio, and RF noise.

The US power grid may be 99.9% reliable; that 0.1% can wreak havoc on computers and other sensitive electronics. Moreover, I recently

learned the hard way that one of the precautions commonly taken to assure uninterrupted, clean power can take down your computer and potentially devastate your entire workshop. First, a bit of background on surge suppressors and uninterrupted power supplies. Surge suppressors are the most affordable and simpler of the two technologies, often comprising a 15 to 20A circuit breaker and at least one metal oxide varistor (MOV). Unfortunately, some power strips sold as “surge suppressors” are current surge suppressors — meaning they contain a circuit breaker and don’t clamp voltage surges. Voltage surge suppressors clamp the voltage to 150 to 250 VAC, depending on the MOVs or other components used in the circuit. Furthermore, a quality MOV-based surge suppressor will employ three MOVs: one from hot to neutral; and one each from hot and neutral to ground. When a voltage spike appears across one of the MOVs, it conducts — dissipating the power within the ceramic device. Large, high-energy spikes can destroy a MOV, leaving a short or open. Hence, the need to locate MOVs between the circuit breaker and the load so that the breaker trips, disconnecting the load from the power mains.

My favorite surge suppressor is a modified Trip-Lite PS4816 — a 16 outlet power strip with a 15A circuit breaker and lighted on-off switch. To the \$55 strip, I added three MOVs: one from hot to neutral; one from hot to ground; and one from neutral to ground. I used 150 VAC/400 VAC clamp MOVs rated at 6,000A peak current and <25 ns response time with good results (Mouser #581-VE17P00151K, \$0.45). The aluminum Trip-Lite is easily disassembled, modified, and reassembled. Of course, you can also buy commercial surge suppressor power strips and

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rack-mount power conditioners — with multiple outlets. The better power conditioners, such as the units by Furnman (starting about \$150) — add linear filtering to eliminate RF noise from the power, a real-time voltmeter, sub-ns response time, and over-voltage protection.

The second method of assuring “clean” power is to use an uninterruptible power supply (UPS) — a battery-powered DC-to-AC converter with voltage sensing capabilities. A basic UPS senses when the line voltage falls below, say, 105 VAC, and within a few ms fires up the DC-to-AC converter and switches the load to the converter. Depending on the battery capacity and the load imposed by your computer system, you’ll have from two to 20 minutes to save your work and shut down. More advanced “smart” UPS models respond to both brown-out and over-voltage conditions, add voltage surge suppression for cable modem connections, and automatically power-down your computer equipment. It’s good to remember that a surge can enter your computer, TV, or test gear from any number of paths.

The problem with all of this technology is that it’s all too easy to treat it as plug-and-play. Unfortunately, it isn’t. Your “surge suppressor” may be nothing more than a power strip if the MOV(s) inside were destroyed. When was the last time you tested/inspected your surge suppressors? Moreover, back to the story, when was the last you turned off your UPS for the night or when you went away for the weekend?

This summer, upon returning home after a week away, I detected the unmistakable odor of burning insulation in my workshop. At first, I couldn’t determine the source. My computers booted up without a hitch, and the instruments were fine. Frustrated, I took out my hand-held IR thermometer and scanned the room. The case of my UPS — a rather expensive, name-brand model — was simmering at 190 degrees F. There was no alarm or any outward sign of problems. Using heavy work gloves, I disconnected the unit and brought it

outside to cool for a few hours. After another 20 minutes of prying, I managed to extract the two engorged, oozing 12V 7 AH gel batteries. As you can see in the photo, both batteries had burst. Despite the touted “intelligence” of the unit, there was apparently no thermal cut-off. So much for set it and forget it. I no longer leave home without turning off my new UPS. You might consider doing the same — or developing an independent thermal

cut-off circuit project to share with other readers. **NV**



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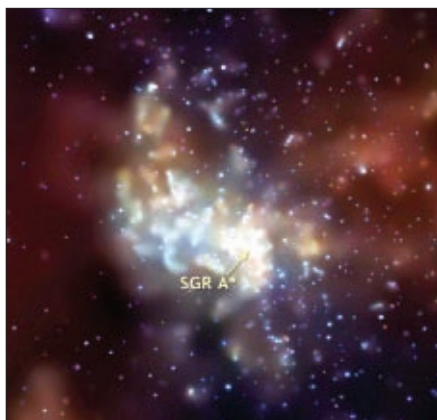
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ETC	-	-	RTC	-	-	-

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

Things are Looking Up...



■ This Chandra image shows our Galaxy's center, with the arrow aimed at Sagittarius A*. Credit: NASA/CXC/MIT/Frederick K. Baganoff et al.

Black holes are pretty well accepted as fact these days. After all, they were theorized as early as 1783 by Rev. John Michell, an amateur English astronomer. They are described by the general theory of relativity, have a definable event horizon at the outer edge, and may last forever. (However, when quantum theory is taken into account, they may actually leak thermal energy [Hawking radiation] and may have a finite life. But I digress.)

For Capt. Jean-Luc Picard, black holes were more common than fleas on a Clingon, so they must be real. The only snag is that no one has actually proven their existence. For obvious reasons, it's impossible to see one, but at least you can observe its effects — if you can get a ringside seat, that is.

Space gases and solid objects heat up as they are pulled closer to the event horizon, so you can learn some things about the black hole from the resulting glow. As it turns out, this one let out a mysterious

major flare about 300 years ago but has been relatively dormant ever since.

Well, astronomers at the MIT Haystack Observatory are busy peeping in, and the latest observation tool is a “virtual telescope” that they created by linking radio dishes located in Hawaii, Arizona, and California. The resulting device measures 28,000 miles (45,000 km) across and, — because its angular resolution enables a technique known as very long baseline interferometry — can generate images 1,000 times as fine as those of the Hubble Space Telescope. The current focus is on the glowing region of Sagittarius A* (pronounced “A-star”), a suspected black hole that resides in the center of our own Milky Way. A* is a jumbo, containing about four million times the mass of the Sun. New observations have been made using 1.3 mm radio waves, which can penetrate the fog of interstellar gas that blurs observations at longer wavelengths, and they have revealed the highest density yet for the concentration of matter at the center of our galaxy.

The astronomers concluded that the source of the radiation likely originates with either a disk of matter swirling in toward the black hole or a high speed jet of matter being ejected by it. This “is important new evidence supporting the existence of black holes,” according to MIT's Sheperd Doleman. “Future observations that create even larger virtual telescopes will be able to pinpoint exactly what makes Sagittarius A* light up.”

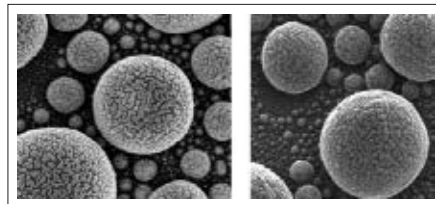
...and Down

Since it was introduced commercially in the 1960s, the scanning electron microscope (SEM) has been

pretty much the cat's meow for nanoscale measurement. But last summer, Carl Zeiss, Inc. (www.zeiss.com), delivered the first helium ion microscope to the National Institute for Standards and Technology (NIST, nist.gov). Dubbed “Orion,” it will be used for improving production in the semiconductor and nanomanufacturing industries. The new microscope uses helium ions to generate the signal used to image extremely small objects, which is similar to the way an SEM works. Paradoxically, although helium ions are much larger than electrons, they can provide higher resolution, higher contrast images.

According to Bill Ward, the instrument's principal inventor, “Because the Orion ion beam appears to be emanating from a region which is less than an angstrom in size, the resulting ion beam has a remarkable brightness. This makes it possible to focus the beam into a very small probe size. Ultimately, this microscope will enable further scientific advancements in a large number of fields, such as semiconductor process control, life science applications, and materials analysis.”

Zeiss has already replaced the original Orion with the Orion Plus, which incorporates many of NIST's suggestions in its design, including an improved cooling system for the



■ An image of gold atoms on tin from a scanning electron microscope (left) has relatively poor depth of field. By contrast, the entire image from a helium ion microscope image (right) is sharp and clear. Credit: NIST.



■ New models in the Sony VAIO® line-up put an HDTV, Blu-ray player, and PC in one box. Courtesy of Sony Corp.

helium source for better imaging.

COMPUTERS AND NETWORKING

New "All-in-One" Desktop

Last September, Sony (www.sony.com) introduced three new all-in-one desktop machines: the VAIO® JS, LV, and RT models. Each one includes an HDTV, a Blu-ray Disc™ player, and a PC in a compact design. Ranging in price from about \$1,000 to \$3,300, they are billed as "ideal for everything from everyday computing to editing high-definition video content."

At the top of the line is the RT High Definition Studio, designed especially for high-def video editing. Its 25.5 in (diagonal) LCD display features XBRITE-FullHD LCD technology and a Blu-ray optical drive that lets you play, record, and edit HD videos in 1080p resolution. In addition to the built-in digital TV tuners, an HDMI In port lets you connect compatible HD cable and satellite boxes. An HDMI output has also been included, allowing connection to an external LCD display or HDTV. The RT series incorporates Intel® Core™ 2 Quad processors, up to 8 GB of RAM, and a terabyte hard drive. It is equipped with a high-speed eSATA port for extra storage, and a CompactFlash® slot. The other models — naturally — offer fewer frills but lower price tags.

Free File Translations

Good news, fellow cheap-skates. If you receive a lot of word processor and graphics files from a wide range of sources, you are bound to run into some that are unreadable by your software. Word, Photoshop, etc., will open only a relatively small number of alien file formats, which can cause you to scrounge the Internet for free conversion utilities. Well, your scrounging days are over. All you have to do is log onto zamzar.com, upload the file, and tell it what you want the converted version

to be. A short time later, it will appear in your mailbox. The basic service is free, and it works with a huge number of document, image, music, video, and compression formats. But — of course — there is a catch. First, you have to wait until they are good and ready to send it to you, which in my test took a couple hours. Not bad. And you are limited to files of 100 MB or less. But for a price, you can get faster conversion, processing of files up to 100 GB, a personal inbox for online storage, and no ads when you log in. The paid levels will run you \$7, \$16, or \$49 per month depending on how much speed and capacity you need.

Watch, Record TV over USB

If you like the idea of linking your desktop or notebook PC to commercial television but don't want to spend a lot of money doing it, there is always the WinTV-HVR-950Q from Hauppauge Computer Works (www.hauppauge.com).

Rather than chucking the old computer, you just plug this \$99 tuner stick into a USB port and away



■ The WinTV-HVR-950Q allows you to watch, record, and pause TV programming on your PC. Courtesy of Hauppauge Computer Works.

you go. You can watch live HDTV

or analog and clear QAM cable TV on your PC, and record and pause the programming at will. The WinTV v6 application lets you watch and record TV in a window or full screen, and WinTV-Scheduler allows recording shows on a daily, weekly, or once-only basis.

The unit is also compatible with Microsoft's Windows Media Center. The package includes a remote control and a portable TV antenna. But note that the unit supports over-the-air HD broadcasts but cannot decode HD signals that come through a cable or satellite box. Analog TV recording will typically consume 1.5 Gb of disk space per hour, whereas ATSC high-def recording gobbles up to 5 Gb, so you may need to beef up your storage capabilities.

CIRCUITS AND DEVICES

Another Shot at Electronic Paper



■ E-paper has been around for several years in various forms, but the reading public has continued to prefer turning the pages of a morning newspaper or lumpy old paperback book to endless scrolling on an electronic display.

Plastic Logic (www.plasticlogic.com) is taking another whack at E-paper with its recently introduced electronic reader, scheduled to hit the market early next year. This one is bigger than most, offering an 8.5 x 11 in display, which makes it feasible for business-oriented material and decent-sized graphics. It is also thinner than the average issue of *National Geographic*, so it won't take up much space in your briefcase.

The reader supports a range of document formats, including the Microsoft Office suite and Adobe PDFs. You can link to the document source through either a wired or wireless connection, and several

thousand documents can be stored internally. As of this writing, no price tag has been attached, but one of the main deal killers of competing products is the high initial cost (e.g., \$359 for the Amazon Kindle and about \$300 for the Sony Reader). Will this be the product that makes paper obsolete? Well, maybe.

Make Your Pet a Photographer



■ The Pet's Eye View camera turns your dog or cat into a photographer. Courtesy of Uncle Milton.

This month's Ill-Conceived Gadget award goes to Uncle Milton (www.unclemilton.com), which appears to be responsible for the Pet's Eye View camera. It's basically just a standard toy digital camera, offering 640 x 380 resolution for 4 x 6 in prints and underwhelming storage capacity of about 35 photos. But the twist is that you can hang it from your dog or cat's collar and set

the timer to take a photo every one, five, or fifteen minutes, thus allowing you to see the world from your pet's point of view.

Is this a good idea? If I attached it to my dog, I'm pretty sure the result would consist mostly of pix of (1) garbage cans, (2) rotting road kill, and (3) the posteriors of other dogs. Come to think of it, maybe 35 photos is plenty. Anyway, you can get one for a suggested retail price of \$49.99.

New Robotics Curriculum

In a move intended to "spur greater interest in science, technology, engineering, and math (STEM) across the globe," Innovation First, Inc. (www.innovationfirst.com), and Autodesk, Inc. (www.autodesk.com), have teamed up to offer a new robotics curriculum package. It is primarily intended for classroom use, but it includes some features that should make it appealing to the home hobbyist, as well. Autodesk has been around for years, providing 2D and 3D design software to manufacturing, construction, and other markets, and its contribution is based on the Autodesk Inventor package, which is used by many professional robotics engineers.

Innovation First is kicking in its VEX Robotics system, which is

already used in more than 2,000 classrooms. The result is the new VEX Classroom Lab Kit, which "provides a custom solution for robotics education that is flexible enough to be applied at multiple grade levels, including secondary and post-secondary." The basic \$699 package contains a set of 17 units, each of which contains a separate lesson, concept, and activity. For a list of included hardware and options, visit www.vexrobotics.com/vex-education.shtml. **NV**

INDUSTRY AND THE PROFESSION

Green Energy Research Center Launched

Aiming to "facilitate the use of green energy sources, reduce the environmental impact of carbon emissions, and alleviate the growing energy crisis," the National Science Foundation (www.nsf.gov) has awarded \$18.5 million to North Carolina State University (www.ncsu.edu) and its partners to establish a new NSF Engineering Research Center (ERC). It will be the first of five third-generation ERCs, each of which will embrace "new dimensions designed to speed the innovation process and prepare engineering graduates who are innovative, creative, and understand how to function in a global economy where engineering talent is broadly distributed throughout the world." (Translation: Hold meetings, generate a slew of position papers, and have some really great lunches.) Dubbed the NSF ERC for Future Renewable Electric Energy Delivery and Management (yes, FREEDM), it will conduct research on how to modify the nation's power grid so as to integrate alternative energy generation and novel storage methods into the existing network. The project includes more than 65 industry partners, 18 state and local government organizations, and about nine other universities and institutes. Results are expected in five years.

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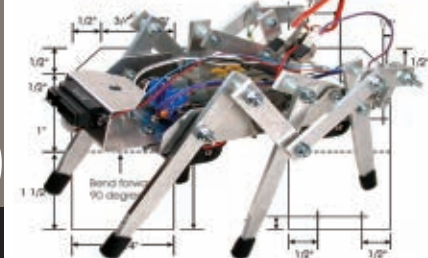
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PART 1

■ BY VERN GRANER

ROBOBENCH: Putting the CrustCrawler AX-12+ "Smart Arm" to Work

IT'S INEVITABLE. When working on a project at your workbench, at some point you'll wish that you had a third hand. When you're holding together two parts that need to be soldered or you need a screwdriver but you don't want to take your eyes off of some small parts to reach for it, an extra hand would be awfully uhm ... "handy." In response to this need, the industry has developed all sorts of "third hand" devices such as the alligator clip "helping hands" sold by RadioShack (Figure 1) or specialized vises such as the ones sold by PanaVise (Figure 2). Though these tools each do their jobs very well, it's up to you to do the (re)positioning any time you want to have your item at a different orientation.

Just a short while ago, some robot enthusiasts and I went to see the movie *Iron Man*. The hero of the story had a pair of autonomous, intelligent, mobile robot arms that would assist him by holding lights and handing him tools as he worked. In one scene, the arm is intelligent enough to know where to hold a magnifying glass to help the hero build part of his suit (Figure 3) by simply observing the human and discerning his needs. Though we obviously have a long

way to go before we get to the level of robotic helpers depicted in science fiction movies such as this, it made me wonder how far off a useful robotic bench accessory was. For example, would it be possible to re-purpose a hobby-level robotic arm to "earn its keep" by helping out on our workbenches?

the venerable RadioShack "Armatron" (Figure 4), purchased in the early 1980s. When I got it home and (of course) disassembled it, I was both impressed and a bit disappointed. Turns out the Armatron used a compact (and complex!) plastic gear box with a single motor to drive all the motions of the arm. The two joysticks mechanically engaged different

CHILD'S PLAY

The first robot arm I owned was

■ FIGURE 3. Robert Downey Jr. as "Tony Stark" in the Paramount feature film *Iron Man*. Photo Copyright © Paramount Pictures.

■ FIGURE 1. RadioShack "Helping Hands."



■ FIGURE 2. PanaVise workbench vise unit.



gear trains with the constantly spinning motor, causing the various joints of the arm to move. Though ingenious in design, it wasn't very "hackable" since there were no individually addressable motors to control. Today, most robot arms you see for sale in electronics/robotics hobby magazines are composed of some plastic or metal parts and a handful of model aircraft-type servo motors. From a hacking/programming perspective, this is a big step up from the Armatron single motor approach.

Most of these robot arms are quite useful for teaching robotic and automation concepts. They do a good job of introducing the subject and showing someone just how complicated a simple human task such as "hand me the TV remote" can be for a robot. I've seen these "educational" robotic arms used to teaching the computational complexity involved in stacking small wooden blocks or moving disks to solve the "Tower of Hanoi" puzzle. Yet, I had not seen one employed doing real work in a real workbench environment. Could it be that a sufficiently powerful

and accurate arm just wasn't available yet?

ENTER THE CRUSTCRAWLER!

When CrustCrawler announced the AX-12+ intelligent arm, I remember reading reports of its strength and accuracy. More importantly, the arm used the Dynamixel servo motors that had real feedback capabilities. This would make it possible to attain new levels of accuracy when using the arm since, unlike a standard hobby servo, it can determine if the arm had actually reached a position. With these advanced features, I wondered if the AX-12+ SmartArm would be able to do real work like the commercial robotic arms used in manufacturing. Could it hand me tools? Could it hold a printed circuit board (PCB) while I was soldering? The more I thought about it, the more I began to wonder why not?

I began to catalog the various tasks that I might need the arm to perform. Using it while constructing devices was the first thing that came to mind. Holding parts or fetching the right tool seemed useful, as well. Need a #2 Phillips? The arm can hand it to you. Need someone to hold these parts while you solder them? The arm can do that AND it won't burn its fingers! The possibilities seemed endless. All I would need was a CrustCrawler AX-12+ to experiment with.

HEY BUDDY, CAN YOU SPARE AN ... ARM?

I spoke with my top-secret

contacts over at *Nuts & Volts* and gave them the broad outlines of the idea I had and asked if they thought CrustCrawler might be interested in this experiment. I told them I thought the AX-12+ would be the perfect candidate for testing out the idea of a useful bench-top robot arm. They put me in touch with Alex Dirks over at CrustCrawler, Inc., and he was happy to send an arm out for torture ... er ... experimentation. I dug through the CrustCrawler website and examined all the various configurations at length. I finally sent off a wish-list to Alex of the parts I thought I would need and, before I knew it, I had a bouncing baby cardboard box on my porch. Time to build!

"SOME ASSEMBLY REQUIRED"

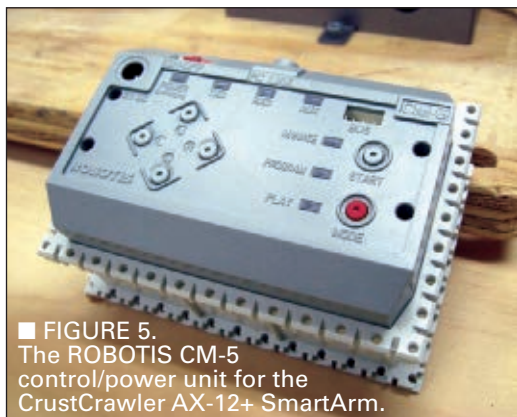
When I opened the AX-12+ box, I was delighted to see little bags of clearly labeled parts and a nice thick detailed manual. Other than some typical hand tools, the only thing I had to supply was the Loctite liquid to lock down the screws so they don't wiggle loose during use of the arm (good practical advice that was stated right at the front of the manual). The arm went together in a couple of fun evenings in no small part due to that very nice thick guide!

Now that I had the arm all together, I was ready to get it to move. Besides the AX-12+ itself, the package from Alex included a cool little interface box called the CM-5 (Figure 5) and the USB2Dynamixel unit (Figure 6). The CM-5 is a record/playback device that can be used to play sequences of moves. It also houses a rechargeable battery pack to allow portable use of the arm and is recharged with the included hefty 12V, five amp power supply.

To program the arm, you connect your PC to the USB2Dynamixel, connect a three-pin cable from the USB2Dynamixel to the CM-5 unit, then connect another

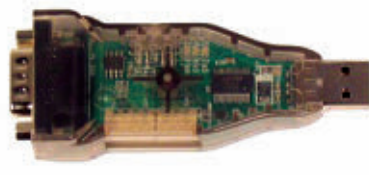


■ FIGURE 4. The author's original 1980's Armatron robot arm from RadioShack.



■ FIGURE 5. The ROBOTIS CM-5 control/power unit for the CrustCrawler AX-12+ SmartArm.

■ FIGURE 6. The USB2Dynamixel USB to TTL/RS-485 adapter.

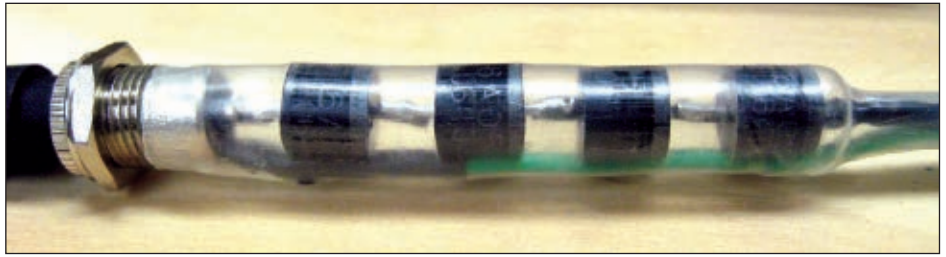


three-pin cable from the CM-5 to the Dynamixel servo in the arm's base. Once the connections above are established, you connect the 12V supply to the CM-5 and you're ready to go. I started out using the Robotis "motion editor" software that comes with the CM-5. Though the software is fairly intuitive, I found it a bit cumbersome to use. It appears to have been designed with the "Bioloid" plastic models in mind. Sadly (at the time of this writing), there was no "template" for my nice new all-metal AX-12+, making positioning the joints a bit tough for me.

TIME FOR SOME GNU SOFTWARE

While digging around for demo sequences on the CrustCrawler website, I discovered a link to the "AX-12+ Arm Sample" project by Scott Ferguson. Scott's code allows you to map joystick controls to the various AX-12+ joints and then "puppet" the arm. Once you move the arm into a position, you can record the joint values as a "pose" and then step forward/backward through these poses. This is very similar to the "teaching pendants" that many commercial robot arms use to create their processes. To top it off, Scott released the software under the GNU public license so all the source code is available, as well (this would come in handy down the road!).

This software looked very promising, however it was designed to communicate directly with the Dynamixel servos and would not talk to them through the CM-5. I would have to remove the CM-5 from the communication chain in order to get Scott's software to work. Though this would be fairly simple to do, it would leave me without a power source for the arm as the CM-5 was handling converting the 12V from the supply down to the acceptable 9.6V voltage levels required by the servos. As a quick and dirty solution, I took one of the extra three-pin



■ FIGURE 7. Four high-current diodes wired in series to drop the 12V power source.

cables and spliced a 2.1 mm power connector into it and included four high-current diodes in series to drop the 12V from the supply down to a voltage that would not exceed the 10V maximum rating of the servos (Figure 7).

GET A GRIP!

I booted up Scott's software and mapped an old joystick to the various joints of the AX-12+ and, in a matter of minutes, was moving the arm all around the desk. A word of warning for those of you that may end up with this arm: it is strong! I've knocked things off my workbench, dumped over a perfectly good can of Dr. Pepper, put a nice nick in the corner of my LCD monitor, and one time I even managed to smack myself right in the funny bone! If you are using the joystick to control the arm, use caution and make sure breakable things are not in its path. Don't learn this the hard way like I did!

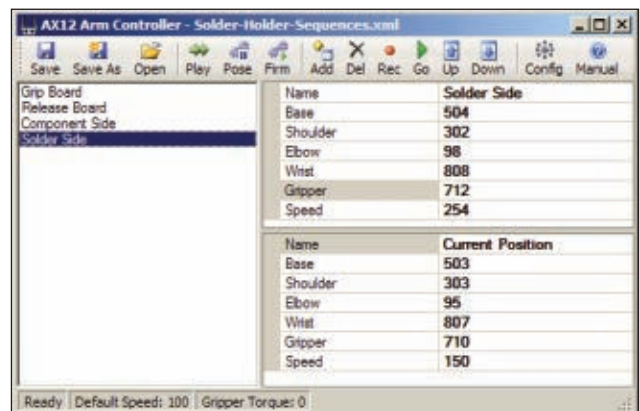
Now that I had the arm in place (and a bandage on my elbow!), I was finally ready to try some work experiments. I started with a task that was both repetitive and fairly common, namely holding a PCB for soldering. When I build through-hole PCBs, I have to flip the board back and forth between solder-side and component-side as I stuff components and then solder them into place. I wanted to see if the arm could do this for me to eliminate the time spent manually

repositioning the mechanical "helping hands" I normally used for this task.

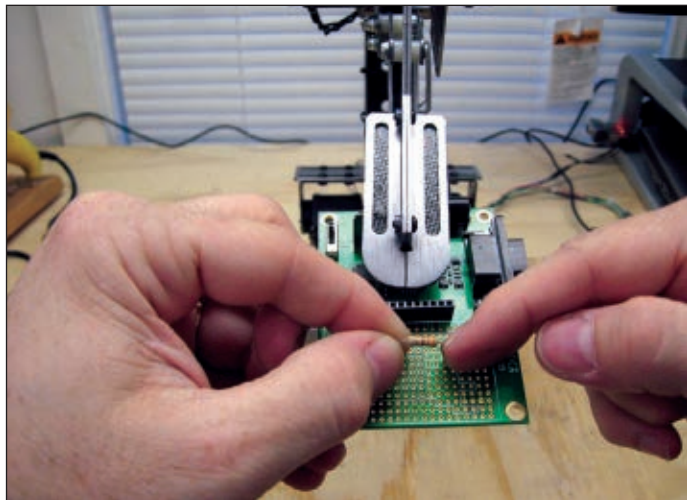
FLIP IT! FLIP IT GOOD!

I started by using the joystick to maneuver the arm into a braced position with the elbow joint resting at the end of its travel, then I moved the shoulder joint so that it was holding the gripper at a comfortable angle for soldering. I then fully opened the gripper and named this pose "Release Board." Next, I brought the gripper completely shut and named this pose "Grip Board." I executed the Release Board pose, placed a small project board in the gripper's range, and executed the Grip Board pose. The gripper took a nice strong hold of the board. I now used the joystick to rotate the wrist joint so the board was solder side up and named this pose "Solder Side." Lastly, I rotated the wrist so the component side was up again and named this pose "Component Side."

So now, with a click of a mouse I could have the arm grab a PCB and hold it while I used two hands to install a component on it (Figure 9), then another couple of clicks flipped the board over so I could use both



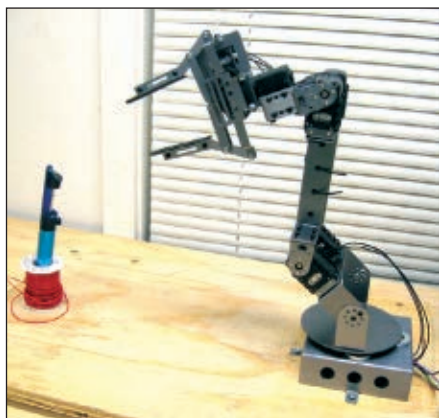
■ FIGURE 8. The AX12 Arm Controller software by Scott Ferguson.



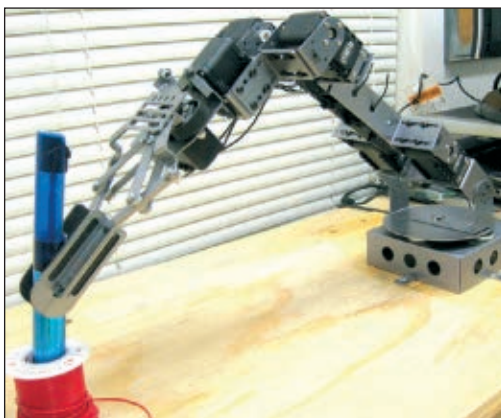
■ FIGURE 9. Placing components into a PCB held by the AX-12+ SmartArm.



■ FIGURE 10. Soldering components into place while PCB is held steady by AX-12+.



■ FIGURE 11. AX-12+ gripper open, ready to reach for the solder vac.



■ FIGURE 12. The AX-12+ gripper clamps down on the solder vac.



■ FIGURE 13. A slight tug removes the solder vac from the AX-12+ gripper.

hands to solder on it (Figure 10). This process was so deceptively easy and the result so useful that I just swaggered on to the next task!

WHEN UNSTOPPABLE OPTIMISM MEETS UNMOVABLE REALITY

The rumble you felt and that

distant screaming sound wasn't an earthquake, it was just my ambitious ideas coming in direct contact with reality. With the board flipping function under my belt, I decided to take things up a notch and see about having the arm hand me one of the other more popular and useful devices on my workbench: a solder vac.

I started by placing a spool of hookup wire on the bench and then placing the solder vac in the center of the spool where it could be easily gripped by the arm. I then used the joystick to move the arm through the series of poses as I had done

above, naming them "Open Gripper" (Figure 11), "Fetch Solder Vac" (Figure 12), and "Offer Solder Vac" (Figure 13). I then placed the solder vac back in the spool and executed the Open Gripper and the Fetch Solder Vac routines. Unfortunately, the gripper missed the vac and ended up dumping the spool over!

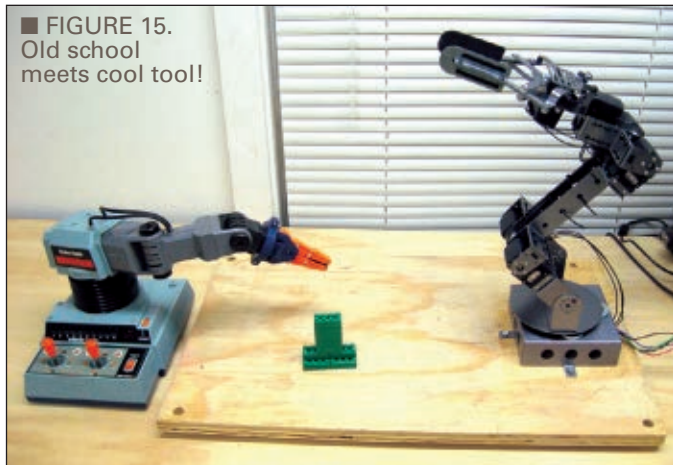
A bit (okay, more like hours) of experimentation later and I discovered that to reliably retrieve the solder vac, I would have to make a much more accurate resting spot for it. Since the arm was reliably repeating the positions I had recorded, the solder vac had to be at the same angle and height every time or there was a good chance the arm would miss.

Logically, this also meant that any tool I wanted to have the arm handle would have to be equally well



■ FIGURE 14. Foot pedal control expected to add hands-free control to the AX-12+ motions.

Going Wireless is Easy!



■ FIGURE 15.
Old school
meets cool tool!

THANK YOU

■ I would like to take a moment to thank the good folks over at CrustCrawler for providing this most excellent robotic arm for use in the project, *Nuts & Volts Magazine* for helping set it up, and Paul Atkinson and James Delaney for their invaluable assistance with this project.

situated. Could be this "hand me a tool" business is a bit trickier than I had imagined! I sat back and started to think about how I could make sure the robot's environment would be as reliable as the arm itself.

SAME BAT TIME, SAME BAT CHANNEL!

Luckily, I've got tough calluses on my ambition and I was able to pull myself from the wreckage of first contact and continue on my quest for a robotic helping hand on my bench. I've managed to sweet-talk one of my regular roboteers into helping write some software to allow foot-pedal control of the arm (Figure 14) and another one to help me build a "tool gallery" to hold the tools exactly where the arm can find them.

Look for all the details of my continuing quest for a helping hand at the workbench in ROBOBENCH — Part 2! As always, if you have any questions or comments, I can be reached at vern@txis.com. **NV**

RESOURCES

■ CrustCrawler (AX-12 Smart Arm Source) — www.crustcrawler.com

■ Forest Moon Productions (GNU Smart Arm software) — www.forestmoon.com/Software/AX12ArmSample/

Fourier Data Loggers

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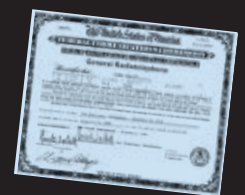
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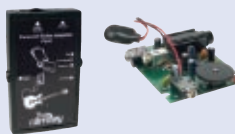


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MK130 3D LED Tree Kit \$7.95

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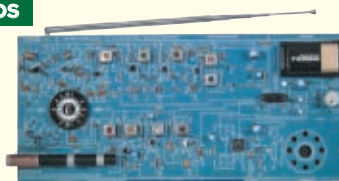


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AM

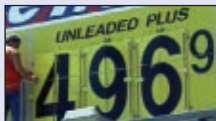
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STAMP APPLICATIONS

PUTTING THE SPOTLIGHT ON BASIC STAMP PROJECTS, HINTS & TIPS

■ BY JON WILLIAMS

SX/B 2.0

About four years ago, Ken Gracey — the crazy cat who runs Parallax — decided that it would be a good idea to provide a free BASIC language compiler for the SX microcontroller family. The BASIC Stamp had been around for some time and there were a lot of power users — myself included — that would benefit from such a beast. The goals were pretty simple: Make it PBASIC-like (though not necessarily source compatible), easy to use in the SX-Key IDE, and allow it to be a useful learning tool for those wanting to explore Assembly language (the dark side!).

You know what? It all happened. SX/B is quite a lot like PBASIC which makes the transition from Stamps to the SX fairly straightforward. It has been integrated right into the SX-Key IDE so you have a choice between Assembly and BASIC, and it uses a single-pass, compile-in-place strategy that allows us to see how every line of SX/B code is translated into Assembly language. And given Parallax's great relationship with its customers, SX/B has steadily grown considerably, becoming a very useful tool for hobbyists and professionals alike.

Of course, many will rightfully point out that I'm a little biased as I was working for Ken at the time and am one of the three amigos responsible for SX/B. That said, now that I don't work for Parallax I'm free to use anything I want. Trust me, I've tried a bunch of neat chips and yet I still go back to the SX and do my coding in SX/B (with Assembly sprinkled in where it's useful). You can too. Listen, for the price of a BASIC compiler for another chip you can buy yourself an SX-Key, an SX protoboard, and a very nice meal for yourself and a friend.

The latest incarnation of SX/B is 2.0 and it has a whole host of nice updates and improvements, but two really big ones that we'll explore here: improved variables use and task management.

LOCAL VARIABLES

The SX — like many chips of similar design — uses a banked memory architecture which means that the program has access to global variables (much of this consumed by I/O and system variables) plus one bank of 16 bytes. In the end, this means that the SX28 — the device most of us will tend to use — allows SX/B just 19 bytes of general-purpose RAM that we can use without having to do anything special. There's nothing more

surprising to the new SX/B user than to “run out of variable space” after reading the SX datasheet and knowing how much RAM exists.

Part of the problem — and I'm partially responsible for this — is that many of us declare a set of temporary variables for use in subroutines and functions. These temporary variables eat into those 19 bytes of general-purpose RAM. In SX/B 2.0, we can define a [memory] stack that allows subroutines and functions to have local, temporary variables, i.e., they're only used during the execution of the subroutine or function and do not consume any of the general-purpose RAM space.

To use locals, we need to declare a stack; in the SX28, that declaration will look like this:

```
DEVICE    SX28, OSC1X2, BOR42
FREQ      20_000_000
STACK     16
```

For the SX28, the maximum stack size is 16. For the SX48, the stack can be as big as you like within the practical limits of the RAM. In case I wasn't clear, this chunk of RAM is used as needed and recovered when a subroutine or function is terminated.

Something to keep in mind: If a subroutine calls another and both are using local variables, we need to ensure that the stack is big enough to handle the requirements of both. Let's say that subroutine A uses three bytes of stack space and subroutine B uses four bytes of stack space. If subroutine A calls subroutine B, then we will need a stack of at least seven bytes. If RAM is tight in your project, you can analyze stack use and set it as required; if not, use 16 (for the SX28) and you'll probably never have to worry about it.

Declaring local variables is just like regular program

variables except that it happens within the bounds of the subroutine, function, or task (more on tasks in a minute). As with regular program variables, we can define bits, bytes, arrays of bytes, and words. For example:

```
` Use: PRINT_STARS count
` - prints "count" stars (*)
```

```
SUB PRINT_STARS
  starCnt VAR Byte

  starCnt = __PARAM1

  DO WHILE starCnt > 0
    TX_BYTE "*"
    DEC starCnt
  LOOP
ENDSUB
```

For the **PRINT_STARS** subroutine, the user will pass a byte value defining the number of asterisks to be printed via **TX_BYTE**. In the past, we would typically use one of our temporary variables — those that consume general-purpose RAM — to hold this value. By defining a local variable as we do above, we are using the stack and not cutting into the general-purpose RAM space; this leaves more variable space for the main part of our program. As you can see, this subroutine uses one byte from the stack. When the subroutine exits, that stack space will be restored to the level it was when it entered the subroutine.

A note of caution: Local variables cannot use the same name as normal program variables. The names of local variables can be the same from one routine to another, but I don't recommend this; use unique names through your program to prevent ambiguity. There is one noteworthy limitation with locals: Since the stack is an array and array elements cannot be used as an index into another array, we cannot use a local variable as an array index. A simple solution is to create a variable in the general-purpose RAM space that will be used for array indexing. We can save the value of that variable when coming into a subroutine and then restore it on the way out. For example:

```
` Use: PRINT_BUF count
` - prints "count" characters from buffer()
```

```
SUB PRINT_STARS
  bCount VAR Byte
  bChar VAR Byte
  saveIdx VAR Byte

  bCount = __PARAM1
  saveIdx = idx

  FOR idx = 0 TO bCount
    bChar = buffer(idx)
    TX_BYTE bChar
  NEXT

  idx = saveIdx
ENDSUB
```

In this example, the global variable *idx* is saved to a local variable, is then used as an index into the *buffer()*

array, and then restored before the subroutine terminates.

In addition to local variables, SX/B 2.0 has some interesting memory management features — some specifically targeting advanced users who may have used Assembly in the past and are accustomed to very flexible memory manipulation. For example, arrays in the SX28 are no longer limited to 16 bytes. We can also force an array to be aligned with the beginning of a bank by using the **ALIGN** modifier with the array declaration. One of the nice new features of SX/B 2.0 is that it includes a very detailed memory use map at the end of the List file — this is quite handy. To be candid, most of our programs will not need or use SX/B's advanced options, but it is nice to have them as our programs — and our programming skills — become more complex and sophisticated.

SX/B AS TASK MASTER

The biggest and most involved update to SX/B 2.0 is task management. Using tasks allows us to set up and schedule automated processes; these are like subroutine but are called by a task scheduler instead of by us. For example, let's say we want to check a sensor every 100 milliseconds no matter what else is going on in the program. With tasks, we can do that pretty easily. Now, this all sounds really neat and very cool and in fact it is; that said, it takes a little bit of setup to get to this level of automation.

First things first. To use tasks, we must declare an interrupt. Task timing will be a derivative of the interrupt rate. As an example, we'll create a simple interrupt that does nothing but allow us to run tasks with a base task "tick" timing of one millisecond — we'd do it like this:

```
` =====
  INTERRUPT 1_000
` =====

Mark_ISR:
  isrFlag = 1

Schedule_Tasks:
  TASKS RUN, 1

RETURNINT
```

Here we've set the interrupt to run every millisecond and, as we have in the past, set a flag on entry for use by external processes. The **TASKS RUN** section sets the task tick timing to one interrupt cycle, so in this case a task tick will be one millisecond. Note that this does not actually launch any tasks; it simply sets up the mechanisms to handle any tasks we define.

Okay, how about an automated blinker; something we might have a use for as an annunciator in a factory process. Let's say we want it to toggle its state every 250 milliseconds. As with subroutines and functions, we have to define the task name before using it:

```
blink_LED Task
```



Note that tasks do not take parameters. Now, in the main body of our program we can set up the task's timing and enable it:

```
TASKS SET, 0, BLINK_LED, 250
TASKS ENABLE
```

By using **TASKS SET**, we have assigned task slot zero to **BLINK_LED** and it will run every 250 task ticks; in this case, every 250 milliseconds. Finally, **TASKS ENABLE** allows this task (and others if defined) to run. The task code itself looks very much like a subroutine except that it is blocked with **TASK** and **ENDTASK**:

```
TASK BLINK_LED
  IF alarmOn THEN
    TOGGLE AlarmLed
  ELSE
    AlarmLed = IsOff
  ENDIF
ENDTASK
```

I stated earlier that we can't pass parameters to a task but SX/B does; with this we can do more than one thing with a given task. We start by defining task slots that point to the same task routine:

```
TASKS SET, 0, BLINK_LED, 250
TASKS SET, 1, BLINK_LED, 100
TASKS ENABLE
```

So, how do we know which slot called the task? The slot number will be passed to the task code in **__PARAM1**. Here's an update to **BLINK_LED** that looks at the slot number that called it:

```
TASK BLINK_LED
  slot  VAR  __PARAM1

  IF slot = 0 THEN

    IF alarmOn THEN
      TOGGLE AlarmLed
    ELSE
      AlarmLed = IsOff
    ENDIF

  ELSEIF slot = 1 THEN

    IF sysReady THEN
      TOGGLE SystemLed
    ELSE
      SystemLed = IsOff
    ENDIF

  ENDIF
ENDTASK
```

For clarity, I've aliased **__PARAM1** as slot. A simple **IF-THEN** structure determines which LED to work with. Note that the code is simple and we will want to keep task code fairly trim. Interrupts still work and will, in fact, interrupt a task, but what we don't want is for a task to be

running when its own timer expires and it needs to be called again. Using tasks can be fun and save some programming headaches but it does take a little time to get used to. Start easy by playing with the LED code. That's where we always start, right? With blinking LEDs. Once you get used to that, you can start combining some of the new memory features with tasks.

For example: Let's say we'd like an RTC without adding a physical device like a DS1320 or DS1307. Here's a possible way of handling that. We'll start by defining the clock variables:

```
clock  VAR  Byte (4)
  huns  VAR  Byte @ clock(R_HUNS)
  secs  VAR  Byte @ clock(R_SECS)
  mins  VAR  Byte @ clock(R_MINS)
  hrs   VAR  Byte @ clock(R_HRS)
```

Whoa, Neo, that's a little different, isn't it? The *clock()* array is easy; what we've done though is create pointers into that array — technically these are just offsets and we could use them with another array altogether (that's really advanced and we'll explore it in the future). By defining the elements this way, we can tell SX/B to use the clock variables and have access to the internals as if they were regular variables instead of array elements. Here's what I mean:

```
` Real-time BCD clock, hh:mm:ss.xx
` - modifies: clock(); values stored as BCD
` - set task to run every 10 milliseconds
```

```
TASK BCD_RTC
  BANK @clock

  INC huns
  huns = huns + $06
  IF DC = 0 THEN
    huns = huns - $06
  ENDIF
  IF huns <= $99 THEN RTC_Done
    huns = $00

  INC secs
  secs = secs + $06
  IF DC = 0 THEN
    secs = secs - $06
  ENDIF
  IF secs <= $59 THEN RTC_Done
    secs = $00

  INC mins
  mins = mins + $06
  IF DC = 0 THEN
    mins = mins - $06
  ENDIF
  IF mins <= $59 THEN RTC_Done
    mins = $00

  INC hrs
  hrs = hrs + $06
  IF DC = 0 THEN
    hrs = hrs - $06
  ENDIF
  IF hours <= $23 THEN RTC_Done
    hrs = $00
```



```
RTC_Done:
  BANK
  ENDTASK
```

This task is designed to be run every 10 milliseconds and will update all of the registers in the software RTC. And, like the DS1302 and DS1307, it uses BCD (binary coded decimal) registers. Note that on entry there is a **BANK @clock** instruction. This is telling SX/B to point to the clock bank instead of the default (general-purpose) RAM bank. What this means, then, is that we can treat the clock variables like regular variables. That said, we cannot use regular program variables here without aliasing them (with the `__RAM()` array).

I'm always on the hunt for neat tricks and this task uses one that helps us to create a BCD RTC (say that three time, very fast). Why BCD? Well, it lets you move the values to displays without the use of decimal division which can, in fact, chew up a fair bit of code space.

If you look at the BCD_RTC task code, it is built of four identical sections, so we'll just look at the hundredths register. The first part is easy: We use **INC** to bump the value by one. What we want to check for now is if the lower nibble of the register moved from \$9 to \$A (10). There are many ways to do this but an elegant solution is to add six to the register. Here's why this is cool: If the lower nibble does now contain \$A then adding six will cause the lower nibble to become zero and the upper nibble to be incremented by one ($\$A + \$6 = \$10$). This is exactly what we want. There is a bit in the SX's status register called DC (digit carry). After adding six to the register, we'll have a look at the DC flag. If this flag is not set (1), then there was no carry between nibbles and we need to remove the six we just added.

At first blush, this may seem like a bit of work but it is, in fact, the most efficient method I've found for incrementing a BCD register. After the increment and digit-carry checks, we examine the register to see if it has reached its limit. If not, now the task exits. Otherwise, the register will be reset and the code drops through to the next register update/check. There is a critical step in this task at the very end — note the lone **BANK** instruction. This causes SX/B to point back to the default RAM bank. We need to do this for the rest of the program to operate correctly. One last note on the `clock()` array.

If we're not pointing to the clock bank as above, then we need to access values through the array itself, like this:

```
IF clock(R_SECS) = $10 THEN
  TASKS STOP, 1
ENDIF
```

With this little bit of code, the RTC task will be stopped when the clock seconds register reaches \$10. Note how we've created a constant called R_SECS that makes using the `clock()` array obvious; obvious is always good. We can also suspend a task which allows it to restart after a pre-determined break; we'll get into

that in a future article.

NEW TEMPLATE — PLEASE USE IT

Finally, I have included an updated SX/B template in the download file on the *Nuts & Volts* website at www.nutsvolts.com. Please install this in your SK-Key IDE templates folder. The new template is better organized, especially with the location of the **PROGRAM Start** directive. With tasks, the interrupt code grows quite a bit and by moving SX/B's internal start-up code (which is placed at **PROGRAM Start**) after the subroutine, function, and tasks declarations we are less likely to have those declarations pushed out of the lower half of the code page — a situation that will cause an error

I know we've just scratched the surface of these topics but this is still some pretty powerful stuff. In the coming months, we will continue to explore and exploit SX/B's cool new features. As ever, I encourage you to play, and if you're willing, participate! SX/B 2.0 is what it is because Parallax and compiler engineer, Terry Hitt, are open to making it better for all of us. You, too, can have a say in what comes next. How many products do you get to do that with?

GO FORTH AND BE PROSPEROUS

An interesting thing happened with a few of my recent columns. I have been contacted by some readers vis-à-vis quasi-commercial ventures with the project designs. A gentleman named Andrew wanted to provide a kit based on the VEX decoder article (see Resources), another suggested a commercial version of the Brake Light Buddy, albeit with some enhanced features, and yet another guy thought he'd do a bulk-buy to save himself and others a little "scratch" on the BLB PCB.

For the record, if you think you can make money or help others with what you've learned from my articles and the code/files that I provide for them, God bless you and please go forward. Just understand that beyond these articles — which I absolutely love doing, especially when I hear your success stories — I can't be involved; my time is just too limited. I hope this doesn't seem harsh or unkind, and I do appreciate your understanding.

Until next time, then, Happy Stamping! — SX/B 2.0 style. **NV**

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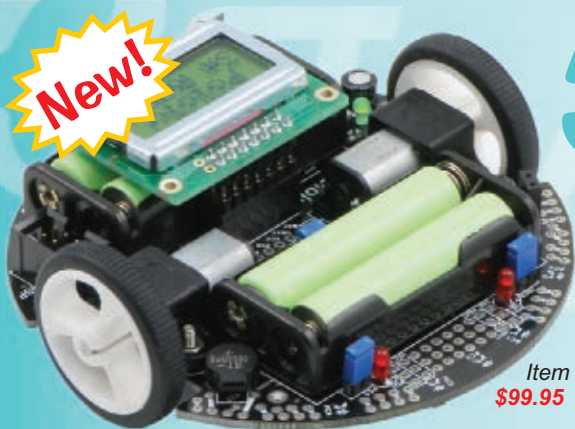
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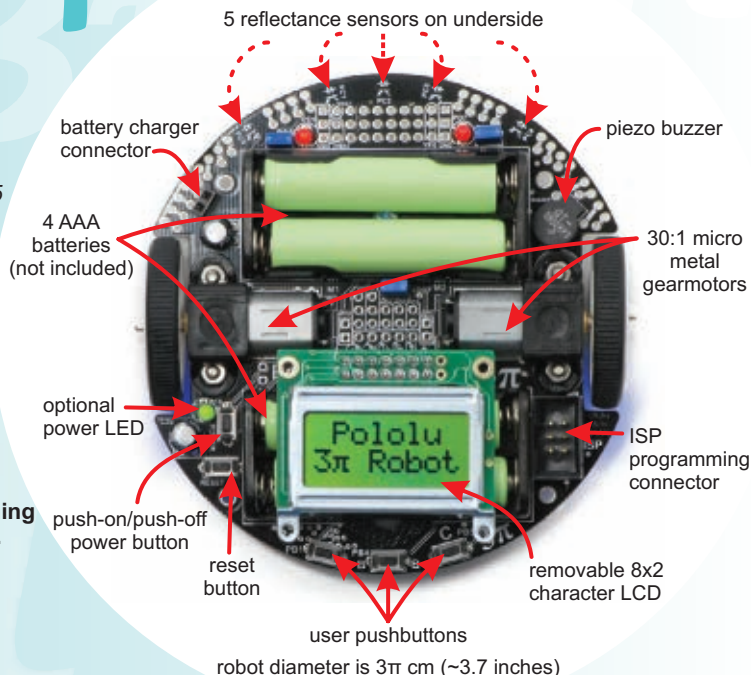
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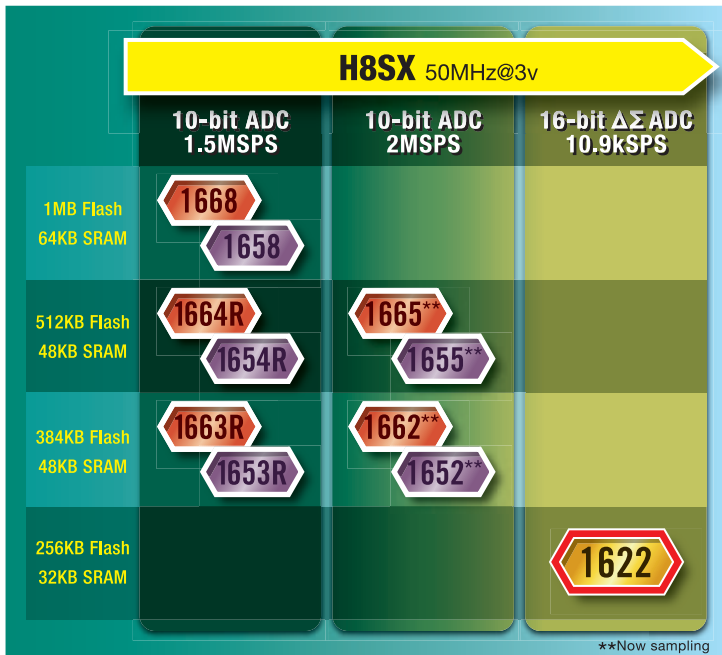
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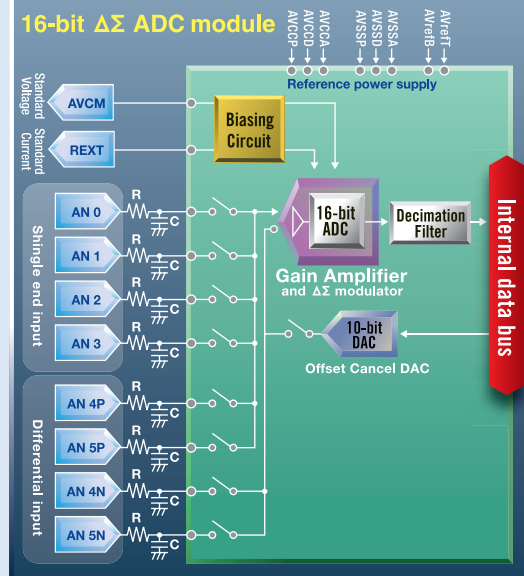
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H8SX Product Lineup



*Source: Gartner *Semiconductor Applications Worldwide Annual Market Share: Database* Hiroyuki Shimizu, 27 March 2008, GJ08218 *This is 2007 ranking

HOT Products	H8SX/1622
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■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

Q&A@nutsvolts.com

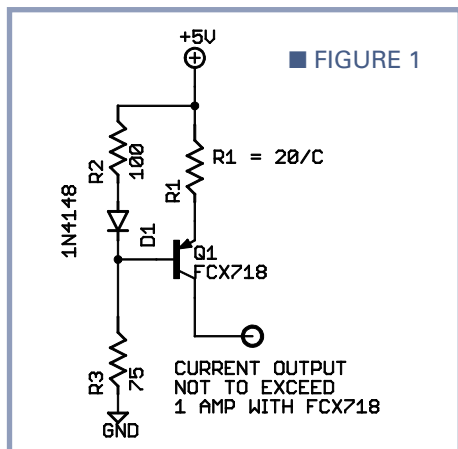
Current Source for Battery Charger

Q I want to build a battery charger using the DS2714 and I am having a problem designing a suitable power supply. Their spec sheet (<http://datasheets.maximic.com/en/ds/DS2714.pdf>) calls for a current limited source of 2A. What would be a suitable voltage for the power supply and how is the current limit implemented?

Also, I am having trouble sourcing the thermistor (Semitec, Fenwal) specified; are there substitutes available from other manufacturers?

— Jack Botner

A The circuit in Figure 1 will do the job. The diode, D1, is to temperature compensate the V_{be} of the transistor. I believe the current should



be $C/10$ for the cell being charged but for two amps, the resistor, R1, is one ohm and R3 is 39 ohms. The FCX718 will overheat at two amps, so substitute 2SB1412 for current over one amp or for higher reliability at one amp. Allied lists the Fenwal thermistors but have none in stock. However, Mouser part number 871-B57540G103F is very close to the Semitec curve. Any thermistor having a β near 3480 will work.

High Current LED Driver

Q I want to build an LED driver that can drive a large number of LEDs from a PWM signal. I want to use a TTL level PWM signal from a small microcontroller that I am using as the dimming control. It works fine for a single LED but now I want to scale it up to use a 12 VDC supply that can handle 150 white LEDs. I plan to have three LEDs in series ($\sim 3.5V @ 20 mA$) which would require about one amp of current switched at around 100 Hz. Thanks in advance for your help.

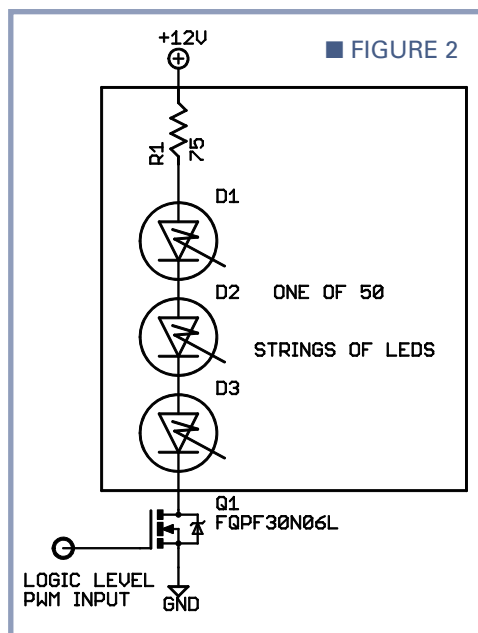
— Michael Gerstweiler

A You need a logic level MOSFET that is capable of switching one amp such as the FQPF30N06L rated 60V @ 22A. You will have 50 parallel strings with 75 ohms in series with each; see Figure 2.

Device to Scare Away Animals

Q In my garden, deer are nipping flowers and buds, so I need a device which can safely frighten them away. I am thinking about a device that will play sound for five to 10 seconds. The stored sound (could be a dog barking or a human voice) should not be the same all the time or the deer will get used to it. Would it be possible to use a memory card into which I could record sounds? The means for starting could be a switch and string, photocells, sound, heat, or movement sensors.

— Ebbe Normark Sorensen
Denmark



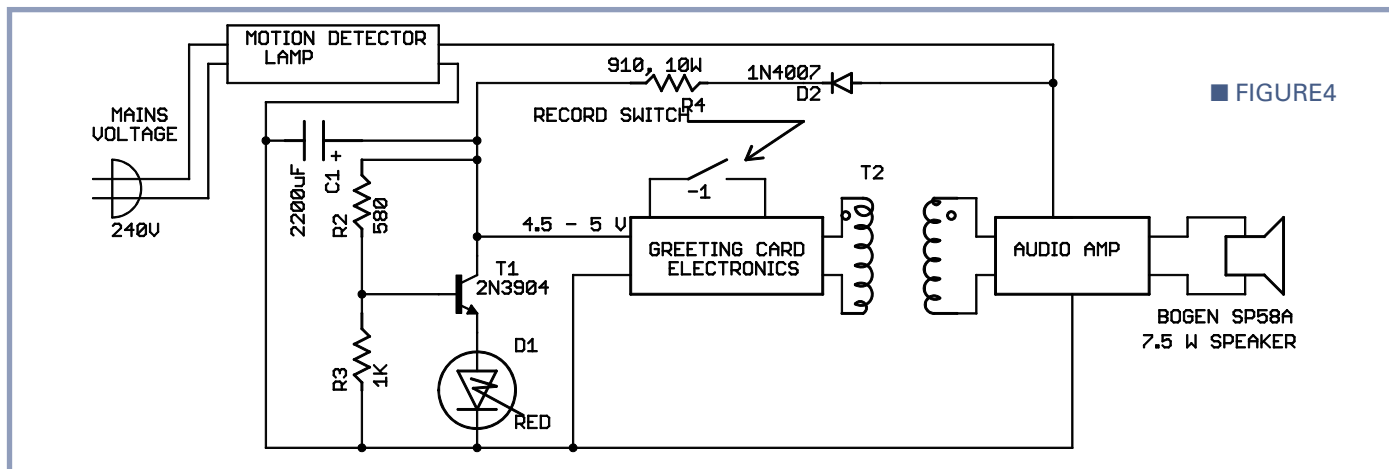


FIGURE 4

A Here is a simple solution: Go to a greeting card store and buy a card with sound. Some of them allow you to record your own message, so you can put the dog barking or whatever you want on it and change it periodically. You will need an amplifier and outdoor speaker to make it loud enough to scare the deer.

To activate the unit, you could hack an outdoor security light and in addition to turning on the light, turn on the sound generator.

Figure 3 is an example of that, but if you want to operate from a battery, consider the STL12LV proximity detector and the circuit of Figure 4. The STL12LV costs nearly \$100 but all you have to do is connect it to power (12 volts AC or DC) and replace the sound generator switch with the STL12LV output switch. It is available from www.residential-landscape-lighting-design.com. An audio amp kit from Qkits will provide enough power; two watts with eight ohm speaker and 12 volt DC supply: <http://store.qkits.com/moreinfo.cfm/FK602>. The speaker is eight ohms, 7.5 watts, outdoor, Bogen #SP58A, available from www.truedataonline.com/index.asp?file=preBuilt&preBuiltSearchID=27816&sort=50&headerImage=.

Figure 5 is the greeting card electronics. After removing the switch, the mounting pad will be the positive supply pad. It is not necessary to remove the batteries but if you do, the negative supply pad will be under the last one. The VSS pad and adjacent test point can be jumped to make the recording play only once.

I was intrigued by this idea enough to build one for myself to keep deer and raccoons from my apple trees. I used the configuration of Figure 3, keeping in mind that the circuit is directly connected to the 120 VAC power and is lethal. For the transformer, T2, I used a small power

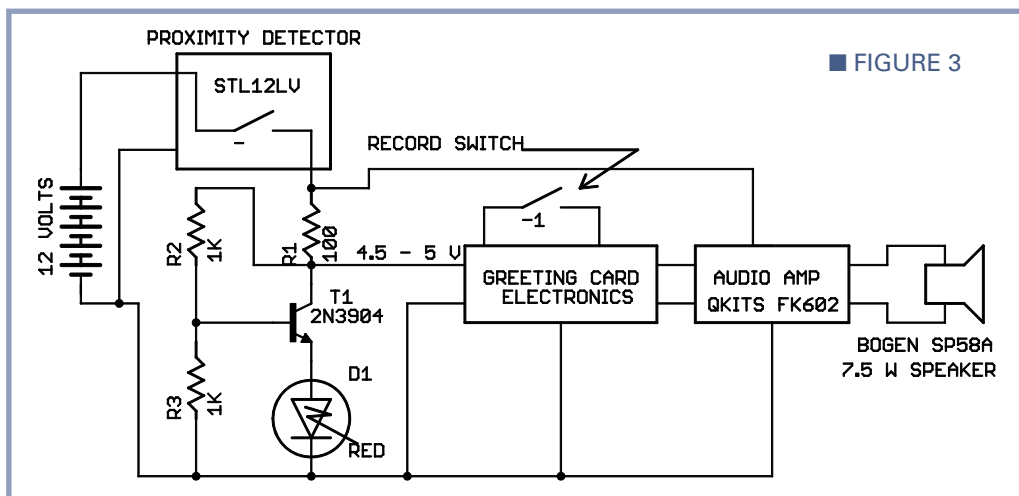


FIGURE 3

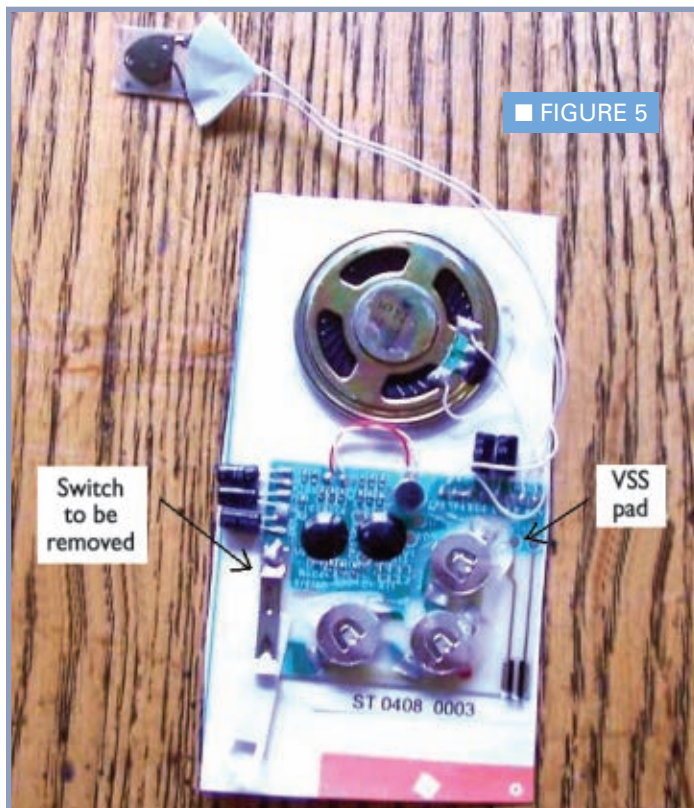
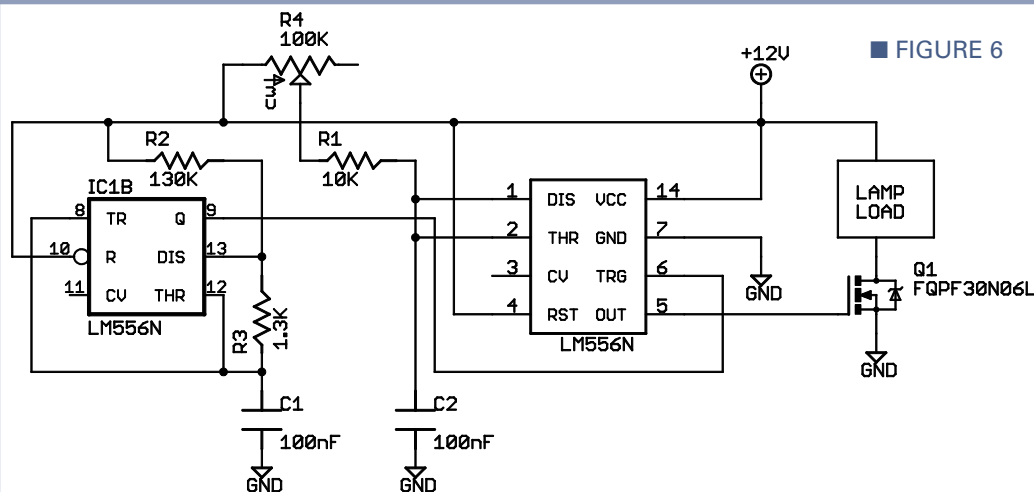


FIGURE 5



■ FIGURE 6

type with two 15 volt windings to give a 1:1 ratio. A 240/24 volt transformer should work also. It is all in a securely fastened plastic box. Also, because the mains voltage in the US is 120 VAC, the resistor R4 is 620 ohms, 5W.

Dimmer for 12 VDC Lamps

Q I have a small pop-up camper with two sets of dual lamp light

fixtures in it. There is only a single on/off switch. I would like to build a couple of dimmers for these fixtures. I think I can do this the easiest with a circuit similar to a switching power supply. What are your thoughts and ideas for a circuit?

— Tom Bohacek

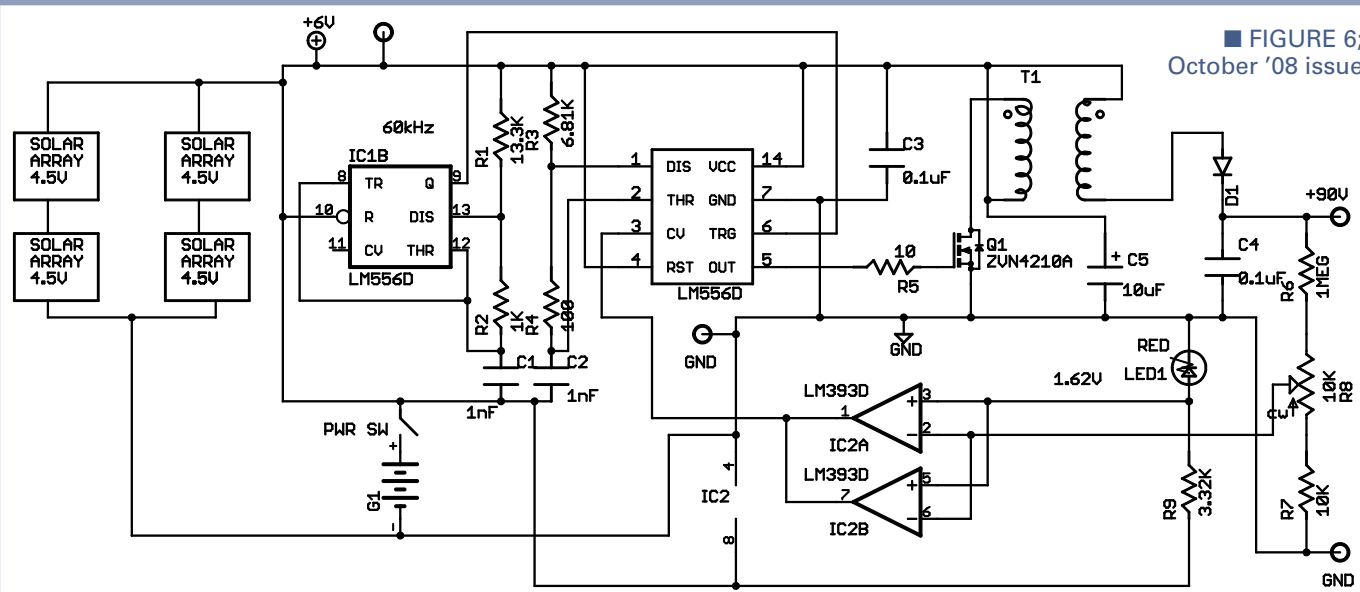
A It is only necessary to chop the 12 volts; 12 volt lamps are normally 40 watts and there are two of them so the current to be chopped is: $I = P/E = 80/12 = 6.7$ amps. A 556 IC driving a MOSFET is the circuit; see Figure 6. The frequency only needs to be high enough that you don't see the flicker, so 100 Hz will work. The first 555 is an astable and provides the frequency. The second 555 is a one

Last month, Figures 6 and 7 (solar power supply) were inadvertently left out of the layout. They are reprinted here for your convenience and are also available at www.nutsvolts.com.

90 VOLT SUPPLY PARTS LIST

■ FIGURE 7; October '08 issue

PART	DESCRIPTION	P/N	SUPPLIER
■ IC1	NE556 dual timer	595-NE556N	Mouser
■ IC2	LM393 dual comparator	511-LM393N	Mouser
■ Q1	NMOS, 100V, 0.45A, logic level	522-ZVN4210A	Mouser
■ D1	400V, 1A, 50 ns, DO-41	821-1N4936	Mouser
■ LED1	Red	156954	Jameco
■ R1	13.3K, 1/8W, 1%	270-13.3K-RC	Mouser
■ R2	1.0K, 1/8W, 1%	270-1K-RC	Mouser
■ R3	6.81K, 1/8W, 1%	270-6.81K-RC	Mouser
■ R4	100Ω, 1/8W, 1%	270-100-RC	Mouser
■ R5	10Ω, 1/8W, 5%	270-10-RC	Mouser
■ R6	1M, 1/8W, 1%	270-1.0M-RC	Mouser
■ R7	10K, 1/8W, 1%	270-10K-RC	Mouser
■ R8	10K trimpot	652-3296Y-1-103LF	Mouser
■ C1, C2	1,000 pF, 50V, NPO	81-RPE5C1H102J2P1A03	Mouser
■ C3	0.1 μF, 50V, X7R	81RPER71H104K2P1A03	Mouser
■ C4	0.1 μF, 200V, film	80-R821C3100DQ60J	Mouser
■ T1 Core	F-42510-EC		Magnetics
■ T1 Bobbin	B2510-10		Magnetics
■ Battery	6V gel cell, 1.3 Ah	632-GH613	Mouser
■ Solar Panel	4.5V/90 mA, 2 3/8" square	PWR1241	BG Micro



■ FIGURE 7;
October '08 issue

shot triggered by the first and has a pot to vary the pulse time. You can

get close to 100% duty cycle, but if you exceed it, the duty cycle

becomes 50% because it is triggered every other pulse.. **NV**

MAILBAG

Dear Russell,

In your Q&A column about transformer design, get a copy of *COYNE TELEVISION and RADIO HANDBOOK*. This old book has some good information on transformer design and has copper wire tables. I have seen this book on eBay for about \$10 and will make transformer building easy.

— Edwin Fitzpatrick, W8MFS

Thanks for the info, Ed, I will have to check it out.

Dear Russell,

On page 29 of the August issue, you answered a question about building a vacuum tube version of a solid-state audio amplifier. The tubes were drawn wrong. When I was just getting into electronics almost everything was tubes. At that time, when a dual tube was used, both sides of the tube had the same V designation, and the symbols had partially dashed or sometimes open enclosures. Has this practice been abandoned, or is it now personal preference? Thanks for listening to my rant!

— Paul Baxter

You are absolutely right, I was just

lazy. A full circle draws easily but partially dashed would be time consuming. I don't have a library of tubes and do not plan to have one.

Dear Russell,

I just got my September issue of *Nuts & Volts*. Your circuit in Figure 1 on page 24 is very interesting. But, Mouser has no 762-LH2540T part. Datasheetarchives has no

762-LH2540T nor do they have a LH2540T. So, what is the correct part # for the solid-state relay, in Figure 1?

— Paul Bergsman, N3PSO

I got my Nuts & Volts today and I see your problem. The 762-LH1540T is a solid-state relay, 350 VAC, 120 mA rating in a six pin DIP package, apparently no longer stocked by Mouser. An equal substitute is: 849-LCB110S, \$2.71 ea.

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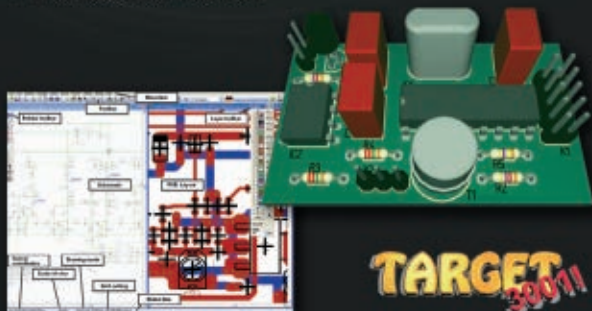
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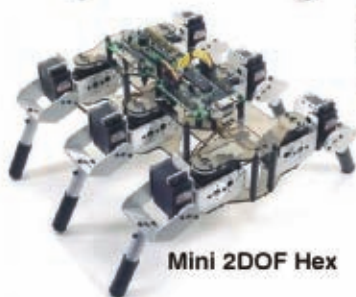
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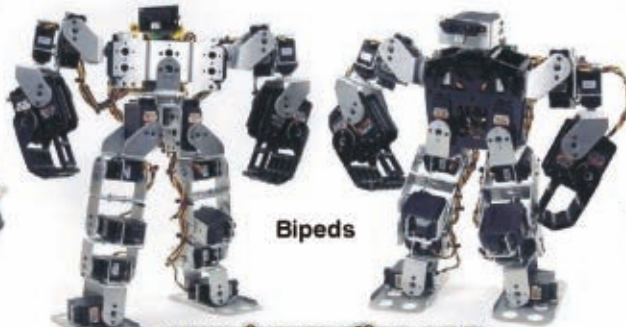
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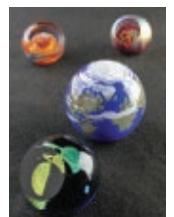
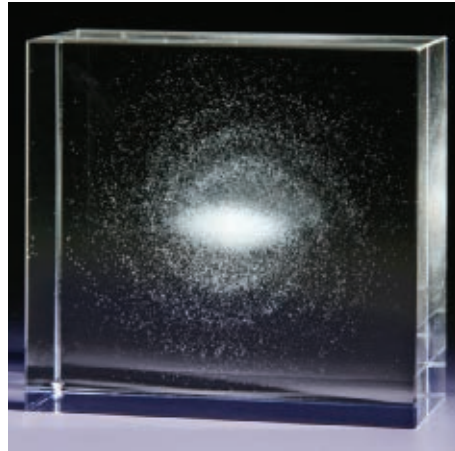
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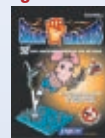
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MICROPROCESSOR CONTROLLED WOOD STOVE

Part 2

BY KERRY BARLOW

In Part 1, software and closed loop theory for the wood stove temperature controller was covered. This article will detail the actual hardware of the controller and how everything interacts.

The wood stove controller may be built using any method that is found easiest to work with. PCBs, hand wiring, wood or plastic boxes all will work fine for this project. I do not intend to go into specific details regarding measurements, connectors, and pin-outs because I fully expect the readers to be using their own parts and ideas as they build this project. Follow my design exactly, or pick and choose what features you wish to use.



■ FIGURE 1

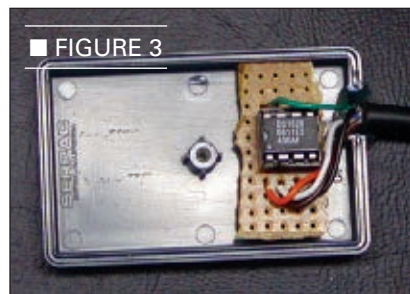


Project Box

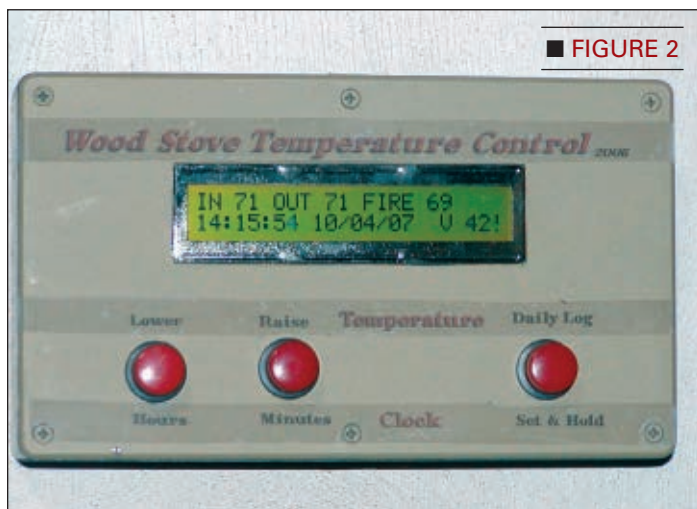
The master control box (Figure 1) is made from a wooden box sold by A.C. Moore. The remote slave display (Figure 2) is mounted in a plastic project box. I used a tiny plastic box to enclose the external DS1620 temperature sensor (Figure 3). Do not forget! Anything used outdoors must be waterproof.

Wiring

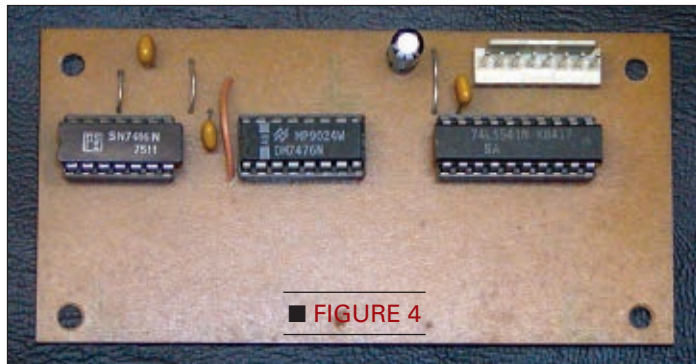
The project consists of hundreds of connections. For mine, I chose a DB-25 serial connector for the low voltage pass



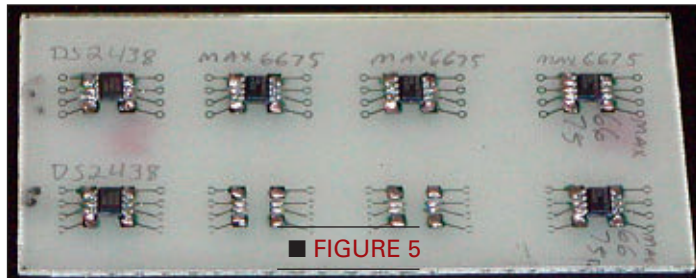
■ FIGURE 3



■ FIGURE 2



■ FIGURE 4



■ FIGURE 5

through coming out of the Master Control box and a six pin high amperage connector for the Stepper motor power. Internal connections are made using standard 0.1" spacing printed circuit board (PCB) headers and female connectors.

Everything is designed in a modular fashion for easy repairs in the future. Connectors should be chosen for easy disassembly and repair. Keep a log of all connections! For example in this particular case, note the following:

Atom pin 1 - DB-25 pin 10
DB25 pin 10 - Slave PCB pin 10 (connector 1)
Slave PCB pin 1 (connector 2) - LCD PCB pin 3

Using this method, in the future you can trace out where the wires are going and what circuit goes through which connector pin. All schematics use pin names that correspond with the same pin names on other schematics.

All switches (both manual and limit switches) use pull-down resistors. Connect one end of a switch to +5V and the other side of the switch to the Atom pin which already has the pull-down resistor installed on the PCB. There are six manual switches and two limit switches. Six manual switches are tied together in parallel for placement in the master control box and the slave box (three in each box).

The system may now be controlled from two different locations. Limit switches are used only for the stepper motor travel limits. Note the following: The closed limit switch CPU pin is shared with the DS1620 outdoor temperature sensor reset line. The DQ/DTA (I/O) pin 6 on the Atom is shared by three components: indoor temperature, outdoor temperature, and the clock. There are four available

unused I/O pins on the bottom of the Atom.

Circuit Boards

This project consists of many different circuits. The stepper motor driver board was built using my own circuit board design (Figure 4), however it is a simple circuit and could just as easily be soldered onto a universal protoboard.

The MAX6675 SOIC (surface-mount chip) is mounted to another circuit board I designed (Figure 5). An interface board is needed to convert from surface-mount to standard 0.1" spacing, and is available from epboard.com.

The clock, indoor temperature, outdoor temperature, and Atom microprocessor are all mounted on universal protoboards. These boards may be purchased in various sizes and from many different vendors (see the Parts List).

Power Supply

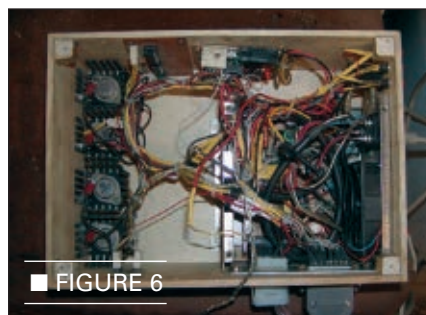
Power for the entire project is provided by a computer power supply seen in the lower right corner of (Figure 6). It has plenty of amperage to drive the stepper motor and run the microprocessor and associated sensors. It is mounted directly inside the Master control box (Figure 6). The end of the control box is cut out to allow access to the power supply plug and fan openings (Figure 7). All extra power output connectors are removed from the power supply simply for aesthetics and space considerations.

Microprocessor Circuit Board

The Atom microprocessor (Figure 8) is mounted on a universal protoboard. This allows you to swap out the board for diagnostic testing. The board includes I/O connectors, serial programming port, power input regulator, power LED, and a reset pushbutton. Note that in the photograph, the pull-down resistors for all switches are mounted directly underneath the Atom itself. The schematic for the Atom microprocessor board is shown in (Figure 9).

Max6675 Temperature Feedback Sensor

I used MAX6675 with a K type thermocouple, purchased my sensor from VirtualVillage.com. Mount the thermocouple assembly in a convenient location inside the



■ FIGURE 6



■ FIGURE 7

exhaust flue pipe. The thermocouple consists of nothing more than a tiny drop of solder on the ends of two heat resistant wires (Figure 10).

You want the thermocouple far enough away from the fire that you do not get much creosote build-up and it is not wise to subject the thermocouple to unnecessary excess heat. Find a good location by using a magnetic thermometer affixed to the exhaust pipe. Pick a location that has reasonable temperature variations without being too hot for safety reasons. The magnetic thermometer also will aid you in setting up your high and low limit temperatures. Your location may not show a range of 100-400 degrees the way mine does, so you will have to adjust the software accordingly. My thermocouple is mounted approximately five feet away from the upper barrel. The temperatures recorded here are the relative exhaust gas temperatures (100-400 degrees), not the actual fire temperature. This will not really matter because as the fire temperature goes up, so does the exhaust gas temperature.

In (Figure 11), the thermocouple assembly is mounted in the flue pipe. The thermocouple itself is not actually visible in this figure. Slide the wire and thermocouple inside a 3/8 inch copper tube for mounting purposes. Attach the copper tube with thermocouple inside to the flue pipe using a right angle bracket. Apply high temperature silicon to the outside wire end of the copper tube to secure the probe inside of it. With the probe mounted inside the copper tube, exhaust gases and creosote are not directly hitting the probe tip and gumming it up with carbon.

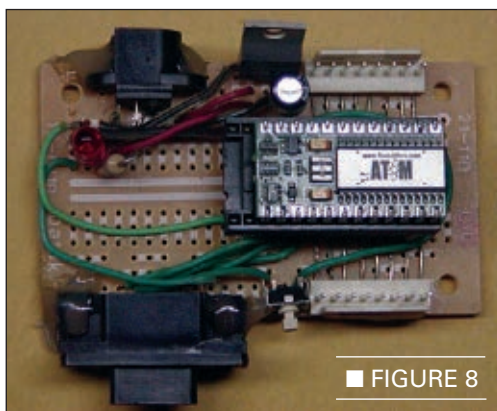


FIGURE 8

Mechanically this protects the thermocouple tip, as well.

Dallas-Maxim recommends that your thermocouple sensor wiring be twisted to prevent electrical interference. A simple method for twisting a long run of wire is to place one end of your paired wire in a vise and clamp the opposite end into an electric drill. Spin the drill slowly and twist the wire into a spiral. Do not over twist! Twelve turns per inch is plenty. The MAX6675 and thermocouple

schematic is shown in (Figure 12).

Stepper Motor Driver Board

I designed my own stepper motor driver PCB (Figure 4). This is a carry-over from an old project. You may easily build your own PCB using a protoboard following the schematic (Figure 13) or purchase a stand-alone stepper motor driver chip, as listed in the Parts List. The stepper coil drive transistors are mounted on the inside wall of the wood project box (Figure 6) using transistor heatsinks. Note in this schematic I sketched the power transistors separately from the driver board for clarity purposes.

Wiring connectors are not shown in the schematic going from the output transistor phases to the stepper coils. A manual shut-off switch is installed for safety reasons and to shut down the stepper motor during summer use.

Switches Stepper Motor and Limit Switches

The stepper motor I used is made by Slo-Syn (Figure 14). It is a 1.8 degree (200 step/revolution) unipolar, 5V, 1.5A motor with a 1/4 inch diameter output shaft. Linkage arms were designed for the

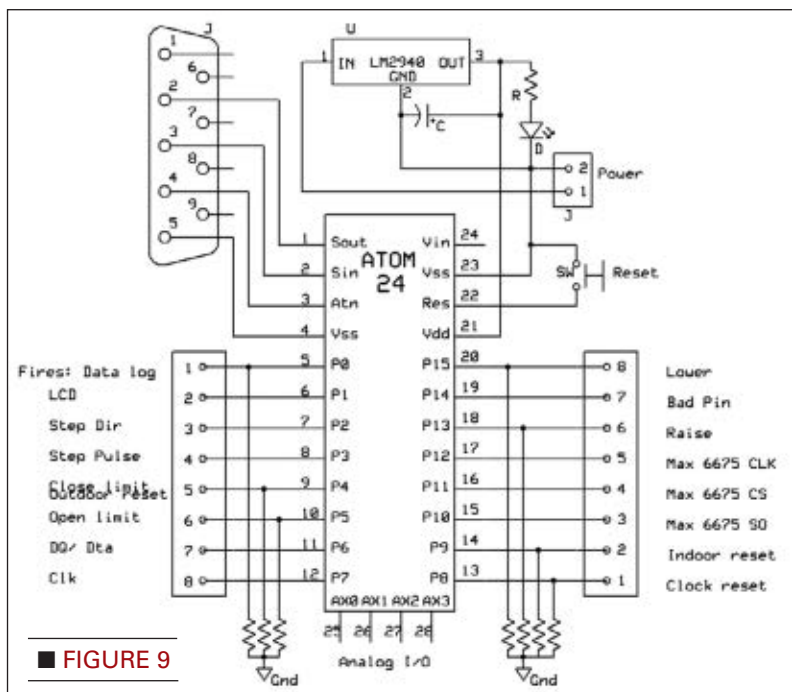


FIGURE 9

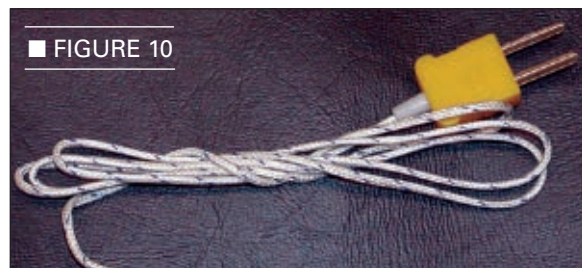
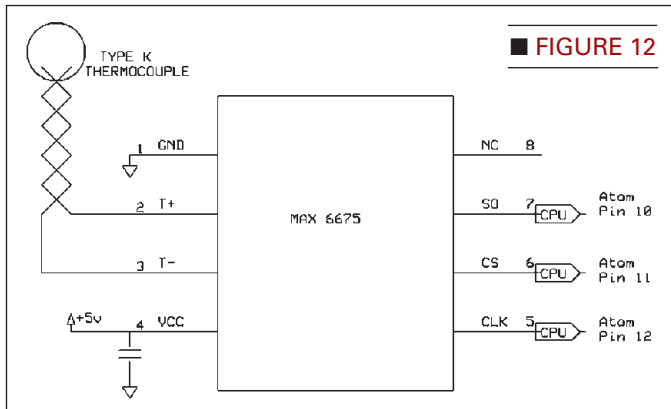


FIGURE 10



FIGURE 11



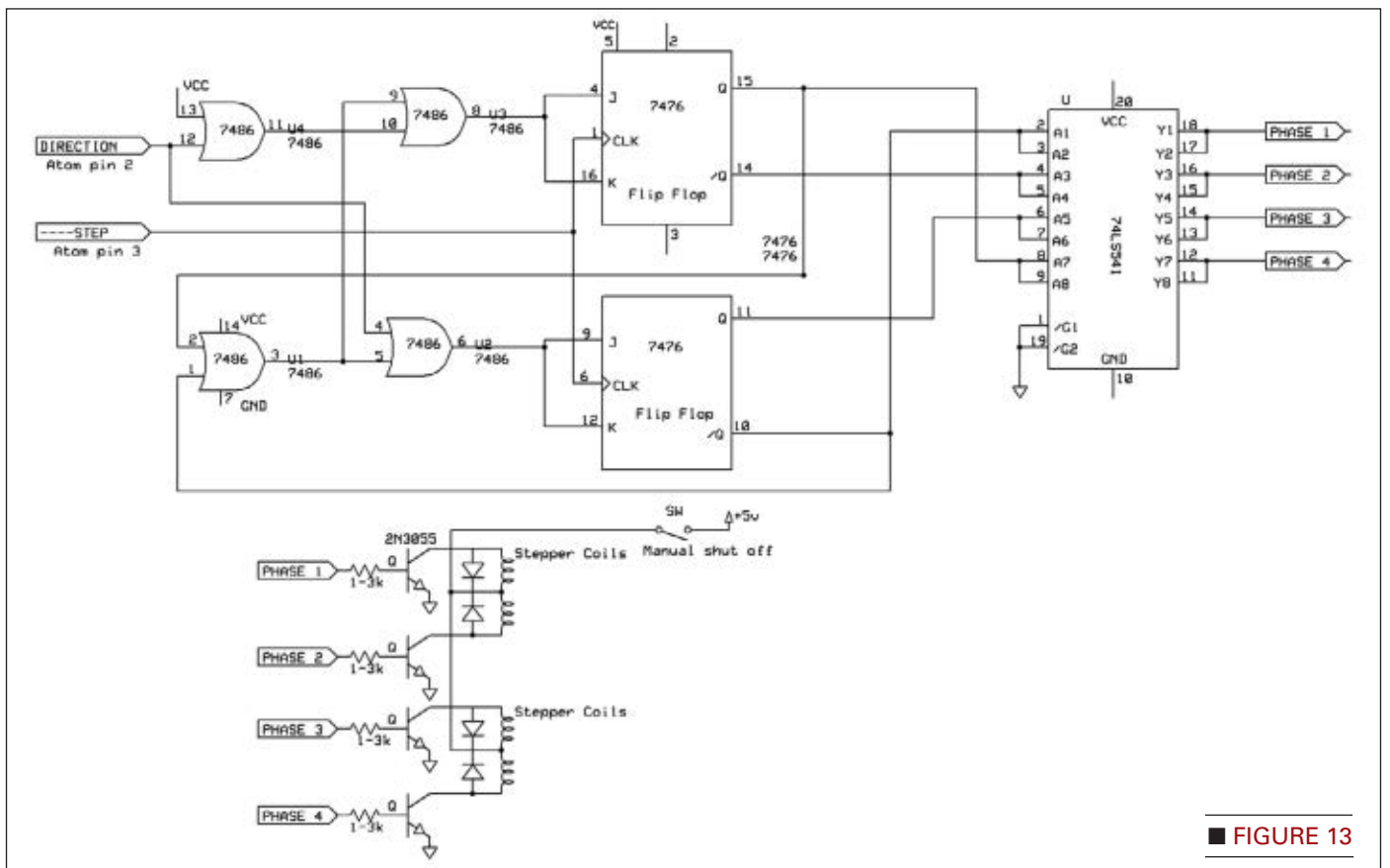
stepper motor shaft and for the exhaust damper shaft. The stepper motor link arm is connected to the exhaust damper link arm using a long 3/16 inch push rod, (Figure 14). Any diameter rod will work as long as it does not flex while in the 'push' mode. There is very little load on the exhaust damper itself, so strength is not necessarily a primary consideration. See Figure 15 for a blueprint of the link arms. Weld a small block of metal to the center of both arms and drill them for a 1/4 inch shaft hole. Next, drill a hole in the block itself for a small set screw that will hold the arm to the shaft. Notice the additional holes drilled in the link arm; these are used for travel adjustment. The outer holes will give more travel/per step than the inner holes. Four holes in both the stepper and the exhaust

link arms provide plenty of adjustment. The push-pull tube is inserted two inches from the center shaft on both arms, ensuring a good range of travel for the damper. Notice in the blueprint the adjustment bolt for the closed limit switch; this bolt is not needed on the exhaust damper link arm.

Two limit switches are actuated by the stepper linkage arm. The first switch limits wide open travel of the damper and the second limits fully closed travel.

Notice again in Figure 14 the red limit switch has an adjustment bolt attached to the linkage arm. This bolt is used for setting the fully closed limit switch position.

The easiest way to make this adjustment is to start a fire and when it is hot and stable, begin closing the damper until smoke begins back-feeding out of the flue (into the



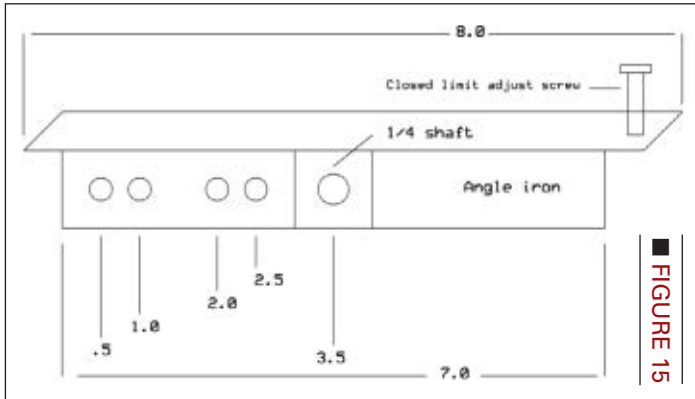


FIGURE 15

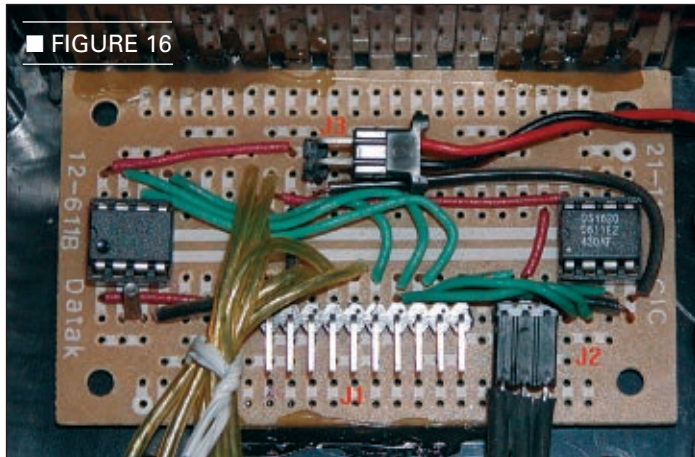


FIGURE 16

house area). Slowly open the damper until the smoke stops. This is the minimum that you ever would want the damper closed while the fire is operating. Attach the push-pull tube or adjust your linkage at this position so that the closed limit switch is activated. In my application, this is approximately 25 degrees open.

DS1620 Indoor and Outdoor Temperatures

The indoor DS1620 temperature chip is mounted on the slave circuit board (Figure 16).

For the outdoor DS1620 sensor, the PCB (Figure 17) is mounted inside a plastic construction box (Figure 3). The edges are sealed with

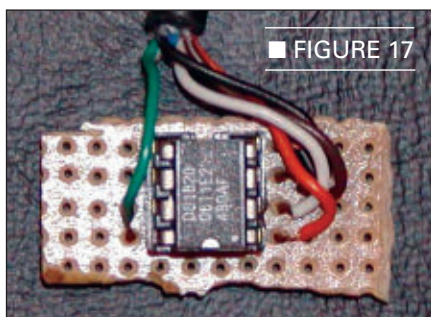


FIGURE 17

silicon to prevent water from leaking inside. Note in the schematics (Figure 18 and Figure 19) that the DS1620 does not have a capacitor or resistor connected to it. The DS1620 connected to the Atom with a cap and resistor like a BASIC Stamp uses will not give an accurate temperature reading if those components are installed.

DS1302 Clock

Display of time and date, as well as a data log of temperatures, is set by the DS1302 clock chip. The clock IC is mounted inside the remote slave display case upstairs (Figure 20). Refer to the schematic (Figure 19) for wiring details. The indoor DS1620 and the DS1302 are mounted on a small universal protoboard (Figure 16). Use an external battery to store clock time in the event of a

NOTE: DO NOT use a capacitor or resistor on DS1620 when using Atom microprocessors.

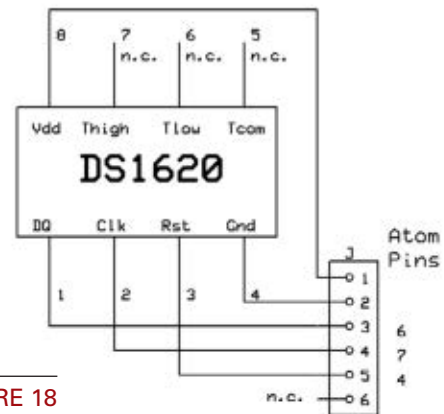


FIGURE 18

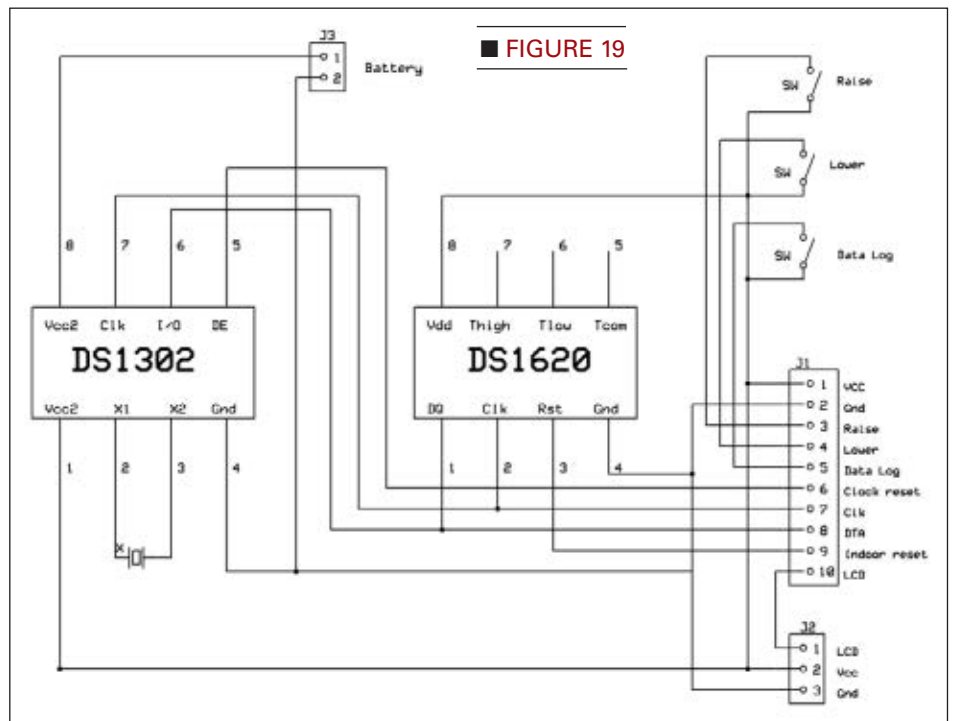


FIGURE 19

power failure. You do not need to get fancy here; I simply used an old battery pack I had in my parts bin and it has worked fine.

Crystal considerations for the clock are important. Dallas recommends various types of crystals that will work with this clock chip. I recommend you follow the Dallas datasheet. Dallas recommends a 32,768 kHz crystal with a 6 pF load capacitance. Parallax sells a compatible crystal and I have listed the order number in the Parts List.

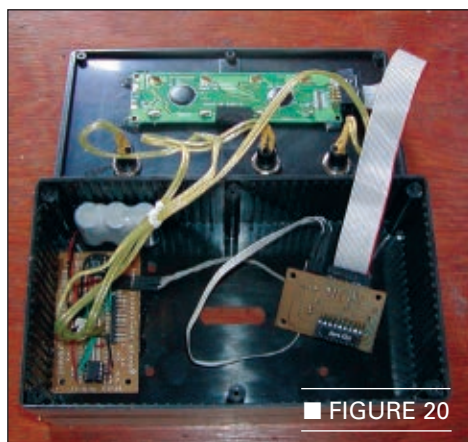
LCD Display

A 24 character by two line LCD display using the Hitachi 44780 parallel standard was installed. The serial-to-parallel driver chip for the LCD comes from Kronos Robotics (www.kronosrobotics.com) and is called a Serial LCD 1 chip (Figure 21). I designed my own circuit board for this chip, however I recommend you purchase the Kronos LCD kit including the chip and PCB.

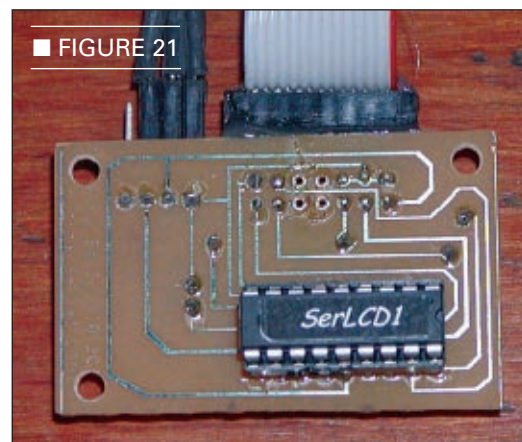
Conclusion

This project was considerably more involved than I originally expected. Many bugs in the software and hardware problems occurred, actually too numerous to mention here.

I advise anyone building this project to start off simple. Start off by breadboarding everything you can and get the hardware and software operating on the bench top first. For example, get your stepper motor and control board working, then get the MAX6675 and thermocouple working. Next, put both pieces together and write some



■ FIGURE 20



■ FIGURE 21

working control loop code. You can easily copy sections from the main program (**woodstove.bs**) – available on the *Nuts & Volts* website – as needed for testing purposes. After you have the control loop working and controlling the wood stove's exhaust damper, add in the extra features such as temperature and data log code. A master and slave control box is not strictly necessary either, but it is here if you need it!

Help is only an email away. I encourage anyone with problems to write me with any questions they may have at admin@mntnweb.com. **NV**

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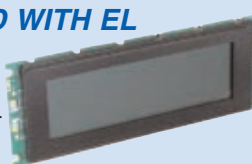
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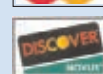
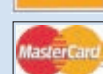
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MICROPROCESSOR CONTROLLED XMAS TREE

BY DAVE BAKER, JOHN TOEBES, AND MARK SCHNELL

Christmas is a great time of year for many of us and provides a great opportunity to share our gifts with one another. Over the years, we have seen a few designs for electronic Christmas Trees, and we created our own design to make as gifts for friends and family alike.



The key to this design and its popularity (not to mention a few “tree custody battles”) has been the combination of the simplicity of the design, the visual appearance of the components on the board, the fun patterns it displays, and the long battery life. By putting all of the components out in the open, they become an actual part of the product and not just the “guts inside the case.” For the electronic hobbyist, it provides an opportunity to really show off those valuable soldering skills.

Our first Tree 1.0 design was done over 10 years ago and we have been talking about all the improvements that Tree 2.0 would have including sound, multi-color LEDs, remote controls, programmability, and even anti-gravity, but we decided that there was a lot of value in just an incremental upgrade in the original design to add USB power, better power management, and more patterns. As can be expected with any project though, Tree 1.1 turned out to be a major redesign of several parts including a new processor with more space, completely new software, and a lot of fun.

We’ve paid particular attention to power management with the Tree 1.1 design so that a single set of batteries will keep the tree running through multiple Christmas seasons. The current record for Tree 1.0 is a tree that ran continuously from before Thanksgiving until after Easter on a single set of batteries. Many 10 year old trees still have their first set of batteries in them, yet are used every year.

Theory of Operation

In addition to the PIC16F685 microprocessor, there are four different hardware functional blocks in the Tree 1.1 design (Figure 1). First and foremost, of course, is the multiplexed LED display; a four column by eight row array of different color LEDs. Next is the power supply block. Finally, to round out the design we have a USB power detect function and a momentary on, pushbutton function. The multiplexed LED display is by far the most interesting, so let’s start there.

Multiplexed LED Display

The human eye is a wonderful organ. It is amazingly sensitive and is the conduit through which vast amounts of information can find its way to our brains. But the eye also has its quirks and idiosyncrasies. The quirk that we are going to take advantage of here is “persistence of vision.” Think feature films with their frame rate of 24 frames per second. Or, your computer monitor’s refresh rate of 60 Hz, 70 Hz, or even 85 Hz. It is this ability of our eye to perceive a rapid succession of slightly changing still images as motion that we will take advantage of here.

This design has 32 LEDs in it. From a practical sense, it would be possible to find a larger microprocessor that had 32 I/O pins and directly connected each LED to one of them. While such a brute force design would work for the tree design (although the cost of the microprocessor

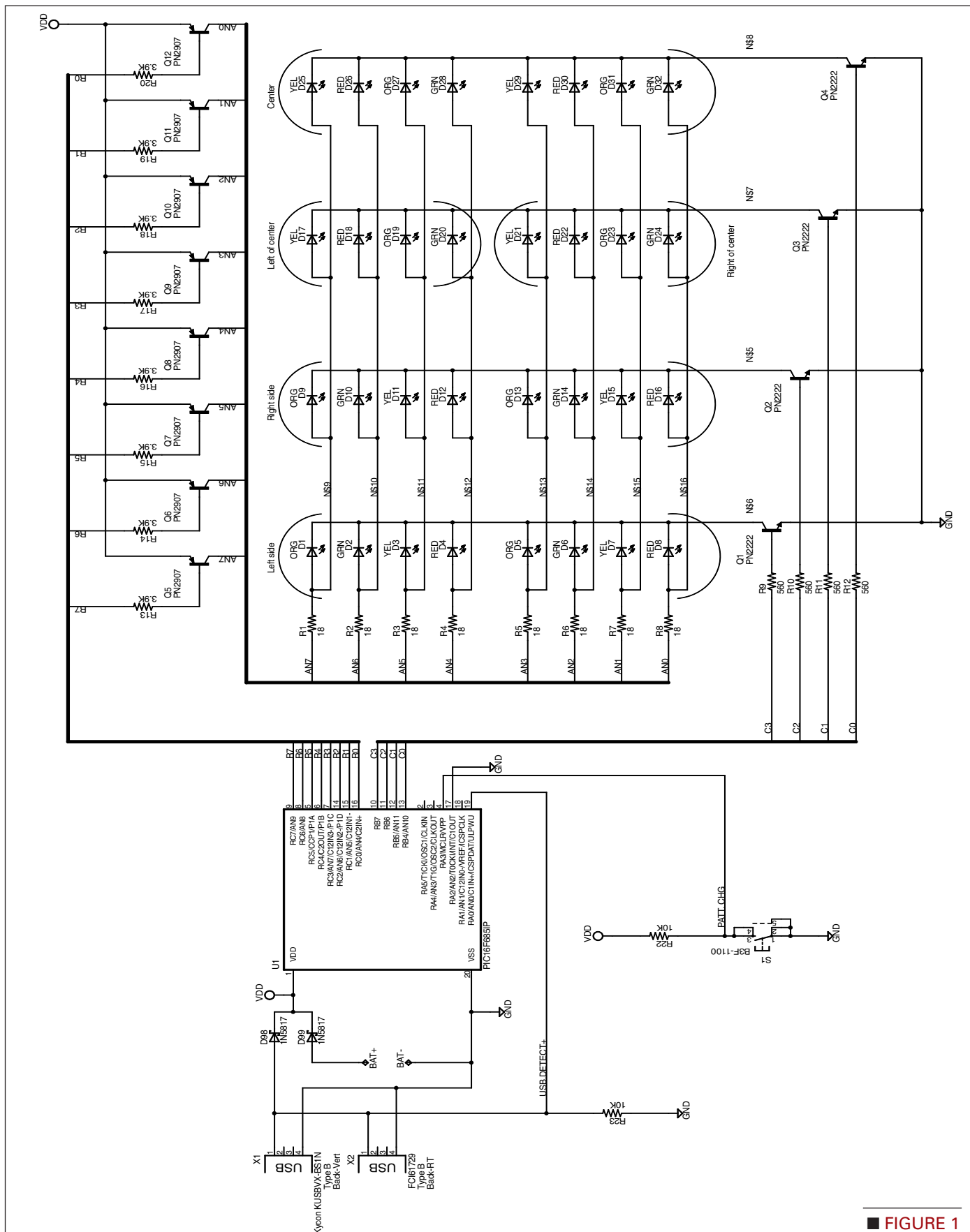


FIGURE 1

would go up significantly), such a strategy is certainly not generally applicable.

Consider a simple black and white computer monitor with a 1,024 x 768 resolution. Using a multiplexed display strategy, such a display could be implemented using 1,024 columns and 768 rows, requiring a total of 1,792 I/O pins from some control block. On the other hand, if a non-multiplex, direct drive display strategy was used for the same display, the control block would need 1,024 times 768, or 786,432 I/O pins. Not a very practical solution. So, let's move back to the more practical and cost-effective multiplexed display strategy.

For this design, at any given instant only one of the four column transistors (Q1-Q4) is turned on. The overall refresh rate of the Tree 1.1 design is nominally 70 Hz (or a refresh period of approximately 14.3 ms). Given that there are four columns in the design, a specific column transistor stays on for approximately 1/4 of the overall refresh period. Thus, each of the column transistors stay on for approximately 3.6 ms before it is turned off and the next column transistor is turned on. Remember this 3.6 ms "column time." We will come back to it.

While a given column transistor is turned on, the software then turns on zero to eight of the row transistors (Q5-Q12). If both a column transistor and a row transistor are turned on, the corresponding LED in the array will have current following through it and will light up. Which row transistors are turned on (and for how long) is dependant upon the particular pattern being displayed. This aspect of "how long" the row transistors are turned on is what controls the relative brightness of the LED.

In this design, we have LEDs that — at any instant in time — are on or off. By varying how long each of the row transistors are turned on for, the design supports varying levels of brightness which our software uses to construct all of the visible patterns. In Tree 1.1, we have approximately 200 different brightness levels. The "level1" LED brightness is obtained by turning on a row transistor for 1/200th of the 3.6 ms column time (a bit less than 2 μ s). Similarly, "level100" and "level150" LED brightness is obtained by turning on the row transistors for 100/200th and 150/200th of the 3.6 ms column time (about 1.8 and 2.7 ms, respectively).

Collectively, this strategy of varying how long the row transistors are on to generate the different brightness levels is called Pulse Width Modulation (PWM). It is a tried and true method to allow a digital system to emulate the continuous behavior of an analog system. In any PWM system, there is a digital signal source that varies its duty cycle or pulse width. (In our case, this is the row transistor control signals; I/O pins RC7-0.) Then there needs to be some sort of smoothing or averaging function. Often it is a capacitor but, in this case, the averaging function is the human eye itself via its persistence of vision.

The only idiosyncrasy remaining is how the microprocessor actually turns on the column and row transistors. The column transistors are NPN devices with

their emitters tied to ground. To turn these transistors on, the software must drive a logic 1 to the associated I/O pins (RB7-4). The row transistors (Q5-Q12) are PNP devices with their emitters tied to Vdd. To turn these transistors on, the software must drive a logic 0 to the associated I/O pin (RC7-0)

The resistors (R9-R12, R13-R20) connected to the base of the column and row transistors have had their values selected such that the transistors will go into saturation, resulting in the smallest achievable voltage drop between the collector and emitter (V_{ce}). This, in turn, results in the largest voltage possible across the LEDs. This results in the maximum LED brightness at low Vdd values; such as when the design is running on batteries that are almost empty.

As it happens, this LED brightness — or at least the relative brightness — was a bit tedious to get right across four different color LEDs. The first thing you find out when researching LEDs is that, if you really care about relative brightness, LEDs are not really interchangeable between vendors. We found it impractical to get the same color LEDs from two different vendors and mix them on the same board. The difference in brightness was quite noticeable and really threw off the visual effects. We also found it was impractical to even get two LED colors from vendor A and two others from vendor B and use them on the same board. The resulting mixed vendor LED displays also had noticeable brightness differences between the colors. In the end, we settled upon — for any given tree — that we had to use LEDs from the same vendor and from the same LED family within that vendor. Only then were the differences in the LED brightness minimized.

Power Supply

The power supply operation is extremely simple. The two possible power sources (USB connector power and D cell battery power) are simply diode OR-ed together. The power source with the higher voltage will be used to power the tree design. The USB connector power supplies a regulated 5 VDC. The two D cell batteries supply a nominal 3 VDC.

In this design, the specific diodes chosen were 1N5817, general-purpose Schottky diodes. Schottky diodes have the property of a very low forward voltage drop. Minimizing the forward drop across the diode is a key consideration when the tree is battery powered. In this design, the overall current consumption is quite low with a peak current of ~50 mA and an average current of less than ~5 mA. With that level of current consumption, the forward voltage drop on the 1N5817 falls into the 0.2 VDC or under range, making a Schottky diode OR-ing strategy a very simple and cost-effective power selecting function.

In practice, any time the tree is plugged into a powered USB cable, the tree will run off of the USB power and the design will receive 4.8 VDC on the Vdd power rail. Otherwise, the batteries are used and the

design will receive 2.8 VDC on the Vdd power rail.

USB Power Detect

As described in the previous section, the Vdd power rail of the design can be either 4.8 or 2.8 VDC. While the operation of the processor will not be affected (the PIC16F685 has a 2.0-5.5 VDC operating range), the LED array is a different matter. If the SW in the tree were left unaware, the difference in the Vdd power rails would appear as a very noticeable brightness difference in the LEDs. To prevent that, the design includes a trivial USB power detection circuit.

If a powered USB cable is connected, the USB.DETECT+ signal will be connected to the USB 5 VDC power pin which will result in the PIC16F685 I/O pin RA0 being seen as a logic 1 to software. If a powered USB cable is not connected, the USB.DETECT+ signal will be left floating and the 10K ohm, R23 resistor will pull the USB.DETECT+ signal to ground, which will result in the PIC16F685 I/O pin RA0 being seen as a logic 0 to software.

Note that while Tree 1.1 uses USB power, it will not appear as any device on your computer. It is only — what

we like to call — a power sucking alien. The peak current of ~50 mA and the average current of ~5 mA make Tree 1.1's power consumption far too low to be noticed by the USB power management functionality in your computer. (The power management gets involved when a USB device wants more than 100 mA continuously.)

Pushbutton

There is one momentary on pushbutton on the design. This pushbutton is combined with the 10K pull-up resistor R22. The resulting signal PATT.CHG is connected to the MCLR- (Master CLeaR-) pin of the PIC16F685. When this button is pressed, the PATT.CHG signal will go low and reset the PIC16F685 through the MCLR- pin. Through a bit of clever programming, this single button functions as both the pattern change button when the tree is active and as the “wake up” button to reactivate a tree that has been turned off. See the software section for more details.

PCB Layout

The layout of this design (shown in Figure 2) was dictated almost entirely by its visual appearance. A typical design would use the electrical properties of the embedded components and/or their functional requirements as the driver for the layout.

Component Placement

The placing of the components was almost entirely driven by “What will the components look like on the board?” The LEDs, obviously, become the lights of the Christmas tree. But what of the other components; what is their role? Well, besides lights, decorations are the other typical item to put on a Christmas tree. Thus, the transistors, resistors, and diodes are all the decorations of the design.

If your house is anything like ours, the excited little ones around the Christmas tree during the decorating process don't always get things just perfect. In that spirit, the decorations of our tree design are not “just perfect.” The decorations of this tree are clumped together here and spread out there, all to make the overall effect more realistic.

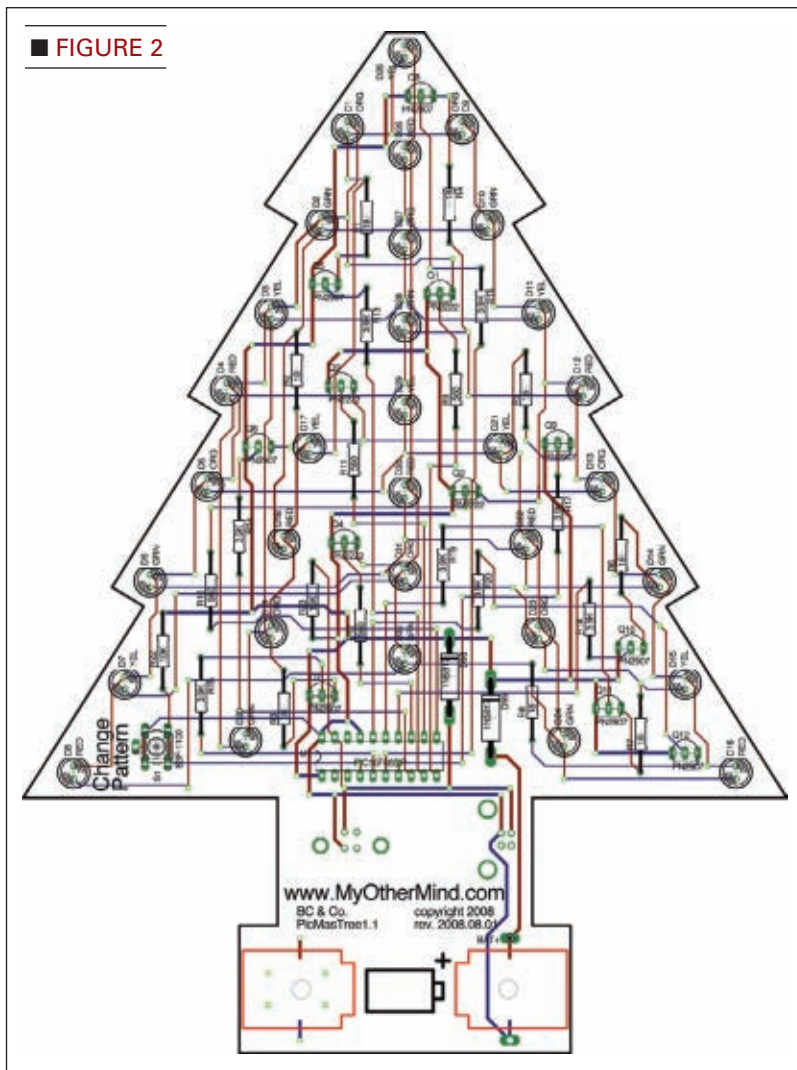
Routing

The last visual attribute that we worked on was the routing. In this case, the routing on the component side of the tree is the vertical routing layer. We deliberately chose vertical routing on the front of the tree to mimic tinsel on a real tree.

Writing the Software

No microprocessor-based design is useful

■ FIGURE 2



In order to fit the code for Tree 1.1 into the processor space, we opted to code everything in assembler using the MPLAB MPASM tool which you can get for free from the Microchip website. Fortunately, you don't have to know assembler to build the tree. We've provided the code already and an available kit includes a pre-programmed PIC16F685. For those of you who are comfortable with assembler, there are a few tricks that we have used to squeeze it all in. All of the code is available for download from our website at www.MyOtherMind.com/go/PicMasTree along with detailed flow charts of how everything works.

To make the code efficient, we had to use a lot of data tables. Since there is no ability to index code memory easily, it has to be done by doing a computed jump into a sequence of RETLW instructions. Due to the bank structure of the PIC16F685, the pattern table has to fit within the same 256 byte page of memory. After debugging misaligned pattern tables and even indexing past the end of the pattern tables, we wrote a set of macros to test for these conditions and warn at compile time of a need to relocate a pattern table. These STARTTABLE and ENDTABLE macros generate the code to automatically manage the PCLATH/PCHIGH registers necessary for the computed jump and make sure that the start and end of each pattern table is in the same page.

Power-up

of Port A is set as an input for reading the USB.DETECT+ signal, and Ports B and C are set as outputs to drive the LEDs. We also make sure that the processor is running at 4 MHz and set up Timer1 to divide the 4 MHz system clock by four for timing how often we refresh the LEDs. We had considered using timer interrupts to allow it to sleep while waiting for refresh, but it would have required an external crystal.

LED Management

```

graph TD
    Reset([Reset]) --> InitProc[Initialize Processor]
    InitProc --> IDLE_CTR[IDLE_CTR := 255]
    IDLE_CTR --> StartupEgg{Startup Egg Set?}
    StartupEgg -- No --> PatternStartup[Pattern := Startup]
    PatternStartup --> RunCodeJunction(( ))
    StartupEgg -- Yes --> ShutdownSet{Shutdown Set?}
    ShutdownSet -- Yes --> ClearShutdown[Clear Shutdown]
    ClearShutdown --> SavePattern[SAVE_PATTERN := Pattern]
    SavePattern --> SetShutting[SET SHUTTING]
    SetShutting --> PatternShutdown[Pattern := Shutdown]
    PatternShutdown --> RunCodeJunction
    ShutdownSet -- No --> ShuttingSet{Shutting Set?}
    ShuttingSet -- Yes --> SavePatternSave[Pattern := SAVE_PATTERN]
    SavePatternSave --> Junction1(( ))
    ShuttingSet -- No --> ClearShutting[Clear SHUTTING]
    ClearShutting --> IncPattern[Increment Pattern]
    IncPattern --> PatternMax{Pattern > Max}
    PatternMax -- Yes --> PatternFirst[Pattern := First]
    PatternFirst --> Junction2(( ))
    PatternMax -- No --> Junction1
    Junction1 --> RunCodeJunction
    Junction2 --> RunCodeJunction
    RunCodeJunction --> SetStartupEgg[Set Startup Egg]
    SetStartupEgg --> SetNextRefreshTime[Set Next Refresh Time]
    SetNextRefreshTime --> MAIN{MAIN}
  
```

■ **FIGURE 3**

■ **FIGURE 3**

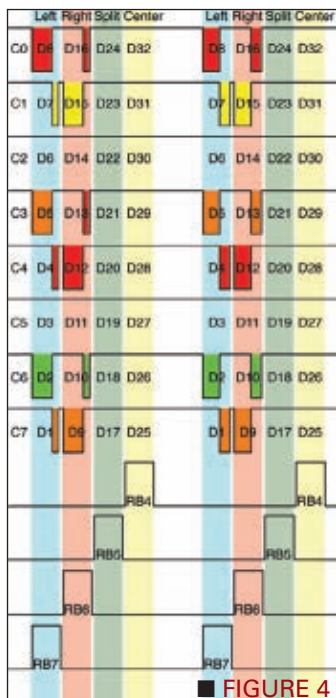
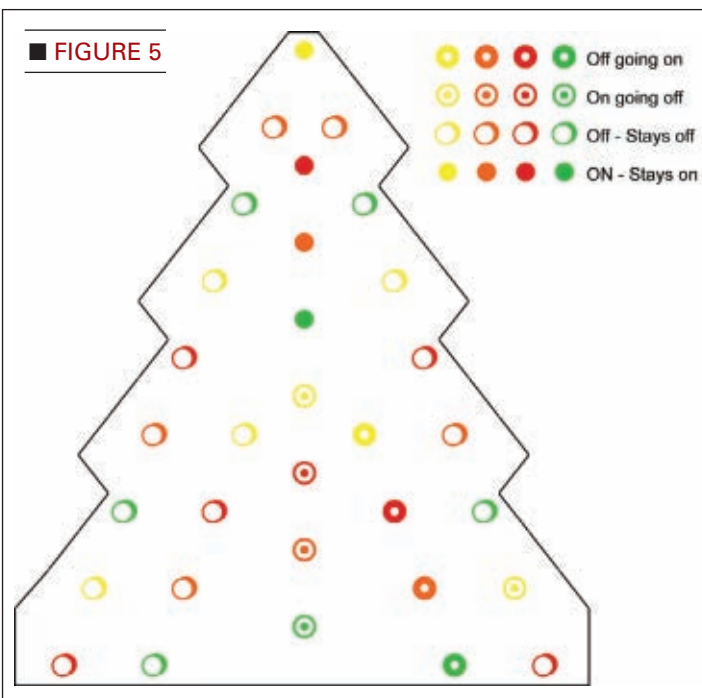


FIGURE 5



we turn the LEDs on for a shorter amount of time. Continuing with our LEDs of interest (D2, D5, D8), the net effect is that the LEDs appear to be dimming.

Patterns

Tree 1.1 comes with several patterns that are displayed either via the pattern data table look-up technique or via the advanced pattern technique. The information for the pattern table is generated from an Excel spreadsheet that you can download from the website. As you can see in Figure 5, we just use the symbols to

one main concern with writing the code for the tree: How do we manage the LED displays? The hardware design decisions for power management also require the software to be just as efficient. This is simply the nature of running on batteries. This means that we want to turn on the LEDs for the minimum amount of time to achieve the brightness levels desired. (One minor challenge that came into play with the use of a USB power option is that we wanted the LED brightness to be the same regardless of the power source.) As a refresh time base, we use TIMER1 to drive a refresh of all four columns approximately 70 times each second (i.e., every 14.3 ms).

We are able to roll all of these concerns into a single routine REFRESHCOL which turns on the LEDs in a single column based on a series of masks and time intervals to apply those masks for. In the case of battery power, these on times are increased by 60% to account for the difference in the power rail voltage levels (4.8 VDC for USB and 2.8 VDC for batteries). This approach allows us to have 200 different brightness levels for any LED by simply changing the amount of time we leave it on for. For a single refresh cycle, we call this REFRESHCOL routine four times — once for each column — and then wait until the timer tells us when it is time to start the refresh cycle again. By slowly increasing or decreasing the amount of time an individual LED is on, the variable LED brightness is achieved. Figure 4 shows an example of two refresh cycles (i.e., two of our 14.3 ms intervals).

For example, when we refresh the first column by turning on Port B, bit 7 and then sending a B'10110110' to Port C, we turn on green LED D2, orange LED D5, and red LED D8 on the lefthand side of the board. When the timer rolls around and we get back to the same column,

draw the state of the tree at each phase (LED going on, off; staying on or staying off) and the included Excel macros examine the symbols to automatically generate the pattern tables that we use in the code. By sizing the window exactly right, we can page down/up in the spreadsheet to see an animation of the lights of the tree. This visual programming approach made it easy to develop a number of the patterns on the tree.

These patterns are represented as schemes in the code marked with a DEFSCHEME macro. For example, the start-up pattern is coded as:

```
DEFSCHEME
PAT_STARTUP, .1, .100, TAB_STARTUP, 0, 0, 0, 0, PAT_MARQUIS,
M_STARTUP | M_NOWRAP
```

which tells us that it will run one time and that each LED sequence will go 100 times — approximately 1-1/4 seconds. It also tells us that we are to use the mask tables without wrapping around when we get to the end. These tables include the initial and ending values for the LEDs. The initial values are found by looking for the TAB_STARTUP9999 entry which looks like

```
TAB_STARTUP9999
    RETLW    B'11111111'    ; 0 - Off, then turn on
```

This tells us that we will start the sequence of 100 times by having all the LEDs off. The other half of this information can be found in the toggle table which has an entry like:

```
TOG_STARTUP
    RETLW    B'00000000'    ; 0 - Off, then turn on
```


which tells us that we will end the sequence with all the LEDs on. We divide our 200 possible levels by the 100 steps and find that we need to increment the time on for the LED by two each step of the way. Assuming we are on battery, the LED is on for six instructions the first time, increasing to 600 instructions by the time we are at the end. The effect that you see is an LED glowing on.

Advanced Patterns

While the pattern tables allow us to do some interesting things, they are limited based on the table size. The extra memory in the PIC16F685 allowed us to write more complex patterns with random numbers to allow us to turn on and off individual LEDs in completely different patterns. For these advanced patterns, we use a trick of pretending that there is only a couple entries in the pattern table and instead of returning a value, we actually use it to jump to the code to generate the advanced pattern. The flowcharts and comments in the code on the website (www.MyOtherMind.com/go/PicMasTree) describe it in more detail.

Building the Tree

While we did put a lot of effort into the actual circuit board design, you can certainly use a perforated wiring board (perf board) and point to point wiring to build your tree. The original prototype was constructed this way, but a printed circuit board (PCB) makes the assembly faster and much easier. The only critical aspect of the circuit is the color and layout of the LEDs. All of the light patterns would lose their effect if the layout and color of the LEDs is not similar. If you choose the perf board route, spray painting the perf board green to resemble a tree beforehand is a nice touch. There is also a different battery holder which is better suited for perf board construction. Visit our website listed in the Parts List for additional pictures, videos, and construction tips.

What sets Tree 1.1 apart from most other projects is that the finished PCB is part of the appeal and uniqueness of the project. Everything from the selection of the components, to their layout on the PCB was done so that the finished project resembles a tree decorated for the holidays. This makes Tree 1.1 a great project for first-time kit builders, as well as seasoned veterans to show off soldering and assembly skills.

Neatness and appearance really count with this project, so we've come up with some construction tips.

When populating the components on the PCB, start with the components with the lowest profile first, then the next lowest, and so on. Here, that equates to installing the resistors first, the Schottky diodes next, the IC socket and switch, then the transistors, LEDs, and finally the battery clips.

Open the resistor pack, sort the resistors into their respective values, and pre-bend the leads. Hole spacing for the resistors and diodes is 0.6". If you don't have a

component lead bender, the technique we use is center a resistor on the silkscreen layout and use the hole pattern on the PCB as a spacing guide. Grasp the resistor lead with the tip of needle-nose pliers between the body of the resistor and just next to the hole, but not over the hole to allow for the bend radius of the lead. Bend the lead 90 degrees with your fingers and repeat for the other lead. Test-fit the resistor into the PCB. Once inserted, the resistor should lay flat against the PCB. You can now bend the remaining resistors to match.

Assembly Technique

Insert the resistors into the PCB. Lay a stiff piece of cardboard over the top, flip the PCB over, and put the whole thing back on the table. Apply a slight pressure on the PCB to gently make sure all the resistors are flush against it and their leads are sticking straight up. Tack solder one end of each resistor, then turn the PCB over and inspect your work. Make sure each resistor is laying flat against the PCB and is centered over the silkscreen layout for the resistor. If one of the resistors is not flush, heat the solder connection and apply slight pressure to firmly seat it (WITHOUT burning your finger tip). Flip the board over and solder the other end of the resistors; re-solder the tacked lead if necessary, then trim the leads. When trimming the component leads, grasp the lead between the thumb and forefinger of one hand and use the other hand to trim the lead. This prevents the clipped lead from becoming a dangerous projectile and also prevents you from finding a clipped lead on the floor via your bare feet. A good sequence to follow is do the two 10K resistors (R22, R23), the four 560 ohm resistors (R9-R12), the eight 18 ohm resistors (R1-R7), and finally the eight 3.9K resistors (R13-R20).

Continue using this technique for each group of like-height components. Insert the components into the PCB. Use the cardboard to hold the component in place and then turn the PCB over. Tack solder one lead per component, then turn over the PCB to visually inspect the component esthetics before soldering all the leads of all the components.

Repeat this technique for the two Schottky diodes (D98 and D99). Diodes are polarity sensitive so make sure that the banded (cathode) end of the diode matches the banded end of the silkscreen layout.

Insert the IC socket into the PCB. Note the IC socket has a notch on one end similar to the silkscreen pattern on the PCB. On components with more than a couple of pins like the IC socket, modify the assembly technique by tack soldering two pins; one each on opposite corners of the socket. Turn the PCB over and make sure the socket is correctly aligned and is flush.

Insert the switch onto the PCB by applying pressure to the body of the switch. The switch is fairly rugged, but it is possible to damage it if too much force is applied directly to the button when inserting it. Again, solder one pin on opposite corners, double check that the switch is

flush against the PCB, and then solder the remaining pins.

Next, insert the four PN2222 transistors (Q1–Q4). Observe that the flat side of the transistor matches the outline of the silkscreen. The body of the transistor should be about 1/4 inch off of the surface of the PCB once inserted. On transistors, use the assembly technique, but tack solder the center lead. Turn the PCB over and make sure the transistors are correctly oriented. Turn the board over and solder the remaining pins and clip the leads. Repeat this step for the remaining eight PN2907 transistors (Q5–Q12).

Next inset the LEDs into the board. LEDs are polarity sensitive so be sure to align them carefully. The cathode lead is identified by a flat spot on the base of the LED and matches the flat spot on the silkscreen. Also, the anode lead on the LED is longer than the cathode lead. Since it's easier to tell red from orange from yellow once orange is out of the picture, insert the orange LEDs first. Take a second to make sure all the short leads are pointing in the same direction to check that all the colored LEDs are correctly inserted. Again, tack solder one lead of each LED, turn the board over, and make sure they're flush. Once you are happy with the appearance of everything,

complete the soldering and clip the leads.

Insert the USB connector on the back side of the tree. The connector will only fit into the board in one direction. To help line up the connection, look for the six-sided plug outline that is inside the square connector body and match that to the six-sided receptacle in the actual USB connector. A gentle rocking motion will help guide the four pins and the two mounting tabs into the PCB until everything is flush. Turn the tree over and make sure all four pins and mounting tabs are protruding on the other side. Double-check the connector is flush and properly inserted, then solder the pins and mounting tabs.

Battery Clips

Attach one pair of battery clips to the front and back side of the PCB using a nylon screw and nut. Repeat on the other edge of the tree with the second pair of battery clips.

Processor

Install PIC16F685 processor (U1) into the socket. Align the orientation dent of the IC with the socket and PCB silkscreen. When doing this, make sure all the pins are squarely lined up with the holes in the IC socket. If it

appears that the pins are too far apart, gently squeeze the pins together. This can be done using your fingers or by laying the IC on its side and applying gentle pressure. Double-check the alignment and carefully insert the IC into the socket, making sure none of the pins are bent or folded over.

As a final inspection, take a look at the component side of the tree. There should be no empty component positions. Flip the PCB over. Take a look at the soldered connections. If everything looks good, then you are ready for the smoke test, to apply power, and watch the lights.

Smoke Test and Debugging

We suggest using batteries for the initial power up. (The battery polarity is indicated on the PCB.) Install two, new D cells. If your assembly skills are in good shape, you should see all of the LEDs light up for about a second then the tree will automatically move into the

PARTS LIST

ITEM	QTY	DESCRIPTION	MOUSER P/N
□ R1-R7	8	18 ohm (brown-gray-black); 1/4 watt 5% tolerance resistor	30BJ250-18
□ R9-R124		560 ohm (green-blue-brown); 1/4 watt 5% tolerance resistor	30BJ250-560
□ R13-R20	8	3.9K (orange-white-red); 1/4 watt 5% tolerance resistor	30BJ250-3.9K
□ R22,R23	2	10K (brown-black-orange) 1/4 watt 5% tolerance resistor	30BJ250-10K
□ D1-D32		5 mm round LED; qty 8 each of red, orange, yellow, and green; KingBright L53ND, L53ID, L53YD, L53GD, or equivalent Avago HLMP-3301, HLMP-3401, HLMP-D401, HLMP-3507	
	8	LED standard red diffused 635 nm, 5.4 mcd	630-HLMP-3301
	8	LED standard yellow diffused 585 nm, 5.7 mcd	630-HLMP-3401
	8	LED standard orange diffused 600 nm, 5.4 mcd	630-HLMP-D401
	8	LED standard green diffused 565 nm, 4.2 mcd	630-HLMP-3507
□ Q1-Q4 4		PNP Transistor TO-92 Fairchild PN2222ATFR or equivalent	512-PN2222ATFR
□ Q5-Q12	8	NPN Transistor TO-92 Fairchild PN2907TFR or equivalent	512-PN2907TFR
□ U1	1	Microchip PIC16F685IP processor	579-PIC16F685-I/P
□ X1	1	USB Vert type B jack Kycon KUSBVX-BS1N-W	806-KUSBVX-BS1N-W
□ S1	1	B3F-1100 Omron switch Omron B3F-1100 switch white cap	653-B3F-1100
□ BC1-4	4	Battery clips; Keystone #89 battery clip	534-089
□ U1.1	1	20 pin low profile IC socket Mill-Max 110-44-320-41-001000	575-199320
□ DC1-2	2	D cell battery; Duracell MN1300 or equivalent	
□ D98-99 2		1N5817 Schottky diode 1.0A 20V; MCC 1N5817-TP	833-1N5817-TP
□ PCB1	1	Printed circuit board; PicMasTree v1.1 PCB	
□ HW1-2 2		Nylon screw, pan head; 6-32 by 1/4"	
□ HW3-4 2		Nylon lock nut; 6-32	
□ HW5	1	Metal screw; 6-32 by 1/2" or 5/8"	
□ HW6	1	Metal nut 6-32; 6-32	

“Marquee” pattern of the Auto Cycle Mode.

(One of the things that we found extremely useful when building the tree is to have a very quick check to ensure that all of the LEDs are functioning. When power is first applied on the tree, we run a special Power On Self Test pattern that simply lights up all the LEDs for a bit over a second and then turns them off. After that test runs, we just launch into the normal sequence of patterns.)

If nothing happens, don’t panic. It is likely something simple. First check the batteries. Are they installed with the correct orientation? Do the batteries really have a charge? Are the processor (U1 in the socket) and the Schottky diode (D99) installed with the correct orientation? Are all the transistors and resistors installed? Do all the transistors and LEDs have the correct orientation?

If you get some of the LEDs lighting up, but not all of them, then you likely have something amiss in the LED display matrix or the row/column drive circuitry. Here are a few hints to work through:

- One LED out: The most likely problem is that the LED was installed with the wrong orientation. Find the flat part on the side of the LED’s base. Is it aligned with the flat part on the silkscreen? If not, remove the batteries and change the orientation of the LED.

The second most likely culprit is a soldering problem with just that LED. Remove the batteries and check for a solder short on either of the two leads of the LED or for a solder splash in the area. Re-touch the leads to ensure a good solder joint.

- Four LEDs out: Have a look at the schematic. Are the affected LEDs in one row (e.g., D1, D9, D17, D25 or D3, D11, D19, D27)? If so, you likely have a problem with the row drive circuitry. Remove the batteries and check the drive components for that row (e.g., R1, Q5, R13, U1, pin 9 or (R3, Q7, R15, U1, pin 5). Again, check for solder shorts on the leads of suspect components and re-touch the solder joints.

- Eight LEDs out: Check the schematic to see if the affected LEDs are in one column (e.g., D1-D8 or D17-D24). If so, the column drive circuitry is the likely culprit. Remove the batteries. Check the column drive components for the affected row (e.g., Q1, R9, U1, pin 10 or Q3, R11, U1, pin 12). Again, check for solder shorts and re-touch the leads of the components in question.

The only other functionality to verify is the USB power. Remove the batteries and plug into a powered USB cable. The tree should power up, light all LEDs for about a second, and then move into the Marquee pattern. If not, there are only three things to check. Is the USB cable really powered? Is the Schottky diode (D98) installed with the correct orientation? Is the USB connector (X1) installed correctly? Check the leads of these components for solder shorts and re-touch them.

PATTERN LIST

- | | |
|--|------------|
| ■ Auto Cycle Mode (the initial Marquis pattern indicates you are in this mode) | ■ OneColor |
| ■ Glowing | ■ Star |
| ■ CycleDown | ■ Blinking |
| ■ Fountain | ■ Swing |
| | ■ Flashing |
| | ■ Drip |
| | ■ OnOff |

Decorations

Paint the top of the transistors with gold or silver paint, add beads (use the via holes to tie them on or hot-glue them to the board). You could even build a box around the batteries so it looks like a present.

Mash the Button!

To turn on Tree 1.1, simply press and release the change pattern button. This will cause the tree to power up and start the Auto Cycle Mode to sequence through the pattern list.

While in Auto Cycle Mode, each pattern will be displayed for about 30 seconds before it automatically changes to the next pattern.

Turning off the tree is a two step process. *Don’t* press the change pattern button for two seconds. Then, a single press will turn it off.

Tree 1.1 has 11 different patterns in it. If you find that you have a favorite one, you can use the change pattern button to cycle through the pattern list and select a single pattern to be displayed all the time. Each press of the button will select the next pattern in the list. Once you get to the end of the list, it just starts over again from the beginning. Remember to press the button quickly or the two second timing to turn it off will come into play.

Building on It

A lot of things go into making a simple tree, but the real contribution to it is your own hand in building and decorating it as a gift. Where else do you get to have your soldering skills on display and put a twinkle in people’s eyes? **NV**

AUTHOR BIO

■ *Dave, John, and Mark have been friends for over 20 years. They have worked together on numerous projects; some for the day job and some for home projects. All the projects involved hardware and/or software design for embedded computing, personal computers, telephony systems, and/or data networking.*

A complete kit for this project can be purchased from the **Nuts & Volts Webstore**
@ **www.nutsvolts.com**
or call our order desk, **800 783-4624**.



HOLIDAY LIGHTS REVISITED

BY PETER STONARD

Even if you don't share my enthusiasm for "blinkie lights," you'll find some interesting nuggets of wisdom from my school of hard knocks to boost your next construction project.

As we ramp up for the holiday season, it's time to decorate our homes and gardens. The Holiday Lights Controller project has been given a minor facelift and some new features.

Introduction

It's funny how some of life's adventures can appear different in the rear view mirror. A couple of holiday season's ago, I was looking for a simple controller to run a holiday light show. Commercial packages —some with music sync and a personal computer as the engine — were available but none fit my budget or simple requirements. So I rolled my own, taking on a project with technical challenges and a hard end date (December 25th or sooner!). I expected to enjoy it for a couple of months and then shove it in the attic with our fake tree before turning my attention to the summer. The project was featured in the November 2007 issue of *Nuts & Volts*. (*PDF reprint available at www.nutsvolts.com*)

While hitting my original goals, I also found some of the project's subtleties to be a worthy opponent! Admittedly, when you build a prototype and then publish an article, you have to cater to others and try to avoid silly mistakes. You also see your work through the eyes of others, who show great insight, find new applications, and push the envelope. So the original hardware has been poked and prodded through the past summer (while still allowing me some time away from the soldering iron).

Here's a round-up of the things that I have learned and an update to the project for anyone interested in jumping in. I don't have accurate data on how many copies of the original design are in use. A couple of dozen

PCB kits and pre-programmed AVR ICs went out from here, and the data package was downloaded from www.AVRfreaks.net over 250 times!

Fading Hopes

The hardest problem to solve with the original design was getting all 32 channels to have independent brightness control. When the first article was published, I had 32 on-off channels working and eight of those were also full range dimmers. At the time, it looked like a couple of evenings would be spent on the firmware code to finish the rest. Wrong! My attempts to do so crashed the μC ; the root cause was trying to do too much with the microcontroller specified in the original design. I used BASCOM macros for the I²C bus commands and had little control over their actual timing, which is quite critical in a phase-angle dimmer circuit.

Here's the solution: a revised I/O card design. The original one remains perfectly good for up to 32 channels of on-off control or eight channels of full range dimming (compare them in Figure 1). Take a look back at the original article; there are four identical I/O cards linked by an I²C bus to the controller card, which has the microcontroller, user interface, and power supply. The solution to the I²C bus problem is to off-load some of the individual channel timing to a new I/O card design, while keeping the original controller card and hardware without

any other changes. The schematics for both are shown in Figures 2 and 3. It does require changing the firmware on the controller card to match the new data bus protocol, with the consequence that new and old I/O cards can't be mixed. We'll dive into the new card's details after covering a couple more show stoppers.

Does Anyone Know What Time it is?

The controller design has an onboard RTC (real time clock) with battery back-up that wakes up the show and shuts it down again each evening, thus saving me from turning on the display manually or installing a mechanical clock timer switch – which is how I did it the year before.

The RTC chip would sometimes be scrambled about five minutes into the lightshow and the data also sent to the LED display on the controller card would be scrambled, but the show kept running as planned. This is a firmware problem caused by using the random number generator macro found in BASCOM Basic. I don't have the skills to drill down and find the actual problem so I rewrote the Basic firmware by trial and error to fix it.

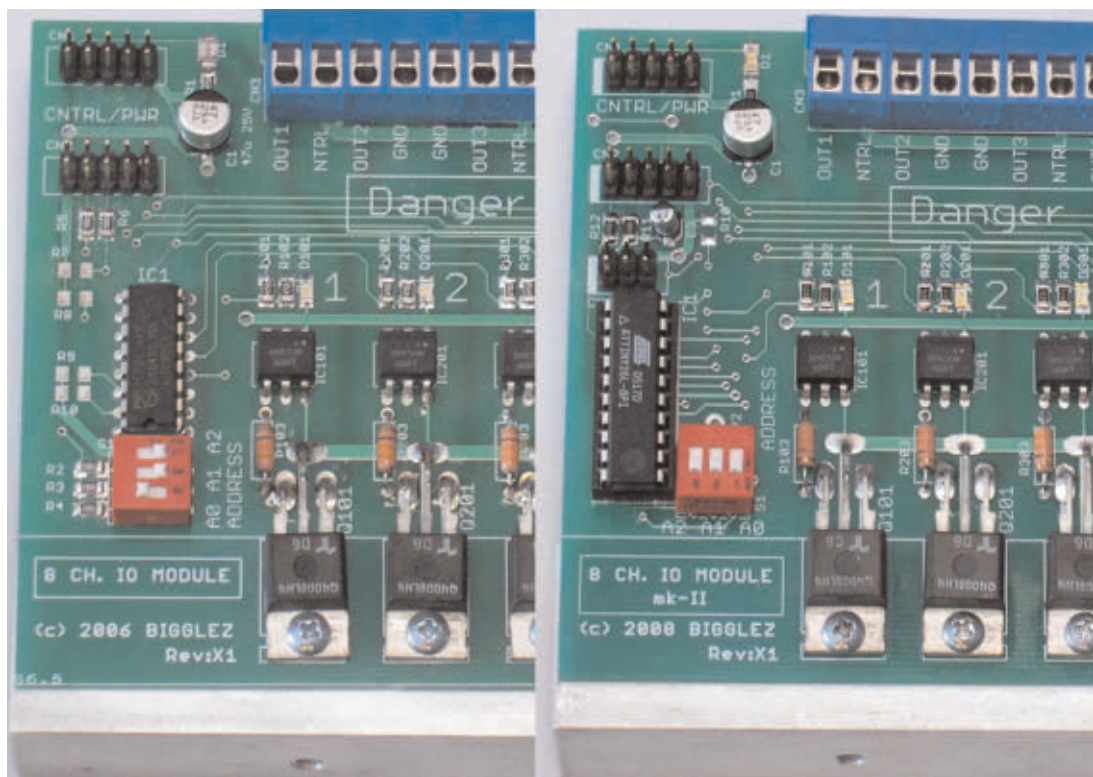
Seeing Double

For the PCBs, I used several SMT parts to save a bit of space, allowing the luxury of an "LCD Port" on the controller. Added on a whim, it would be nice to have an alphanumeric readout, plus I had just discovered the generic 2 x 16 LCD modules at a local surplus store a few months earlier.

Adding support was likely to be one evening of code bashing. What I didn't anticipate is that these generic LCD modules are fussy. Like the random RTC fault just noted, I found the LCD would flicker and finally go dark after several hours, but could be revived by cycling the power. Hmm. Here's a very easy fix: don't send the LCD data as often. Apparently, other hobbyists found the same problem, which is that too much data "overloads" the popular HD44100 controller IC.

Gone in a Blink

I found that due to thermal lag in the holiday light bulbs, the optimum fastest flash time is about a quarter



■ FIGURE 1. Comparison photo of MkI and MkII PCBs.

second, so a sequence with higher update rates isn't needed. A classic marquee chaser, for example, is easy to control with math routines running in the μ C firmware, possibly using random timing elements creatively.

Another gotcha with light shows is to avoid having too many blinky lights. One display in our town looks a lot like they have a "loose wire nut" somewhere. All their holiday light strings are animated to the beat of a music track, and are never steady. A better effect is to have about 20% of the holiday lights remain steady while blinking a few others at any time. I hope that makes sense – if you've seen the "crazy lights" version you'll know what I mean.

Thanks for the Memory

These non-repeating sequences lead to installing an EEPROM on the controller PCB which would be used to store light show sequences, as it's much easier to read non-cyclic data from a memory at set intervals and then repeat it. The original EEPROM that I picked wasn't very large (256×8 bits = 2K) and if the pattern needs to change every quarter second it can only hold about a minute's worth of eight channels, or barely 15 seconds of 32 channels.

Full Address, Please

By luck, I've found a larger memory chip with a 256Kb ($32K \times 8$ bits) capacity that has the same pinout. (Yippee!) Also, the prices seem flat regardless of memory

capacity, so go for the bigger one. I concluded that a unique light show of five minutes duration is plenty.

To use this larger memory requires a firmware change, which now has a two-byte EEPROM address scheme. We still have the problem of programming the EEPROM, and to do so using just the push switch on the controller card would be mental torture. I programmed a couple of EEPROM chips using a hurriedly designed and constructed AVR based EEPROM burner connected to a PC. We're getting into the Vixen territory – a PC-based holiday lights software that can sync music from www.vixenlights.com.

The first version of my light show firmware did not support any EEPROM so it's a non-issue for now, but I am working on it if anyone would like to check in with me by email.

Miscellaneous "Mia Culpa"

With those fairly critical problems behind us, here's a quick run-down of the other goofs I've made. I know how frustrating it is to build something from an article, turn it on, and get nothing!

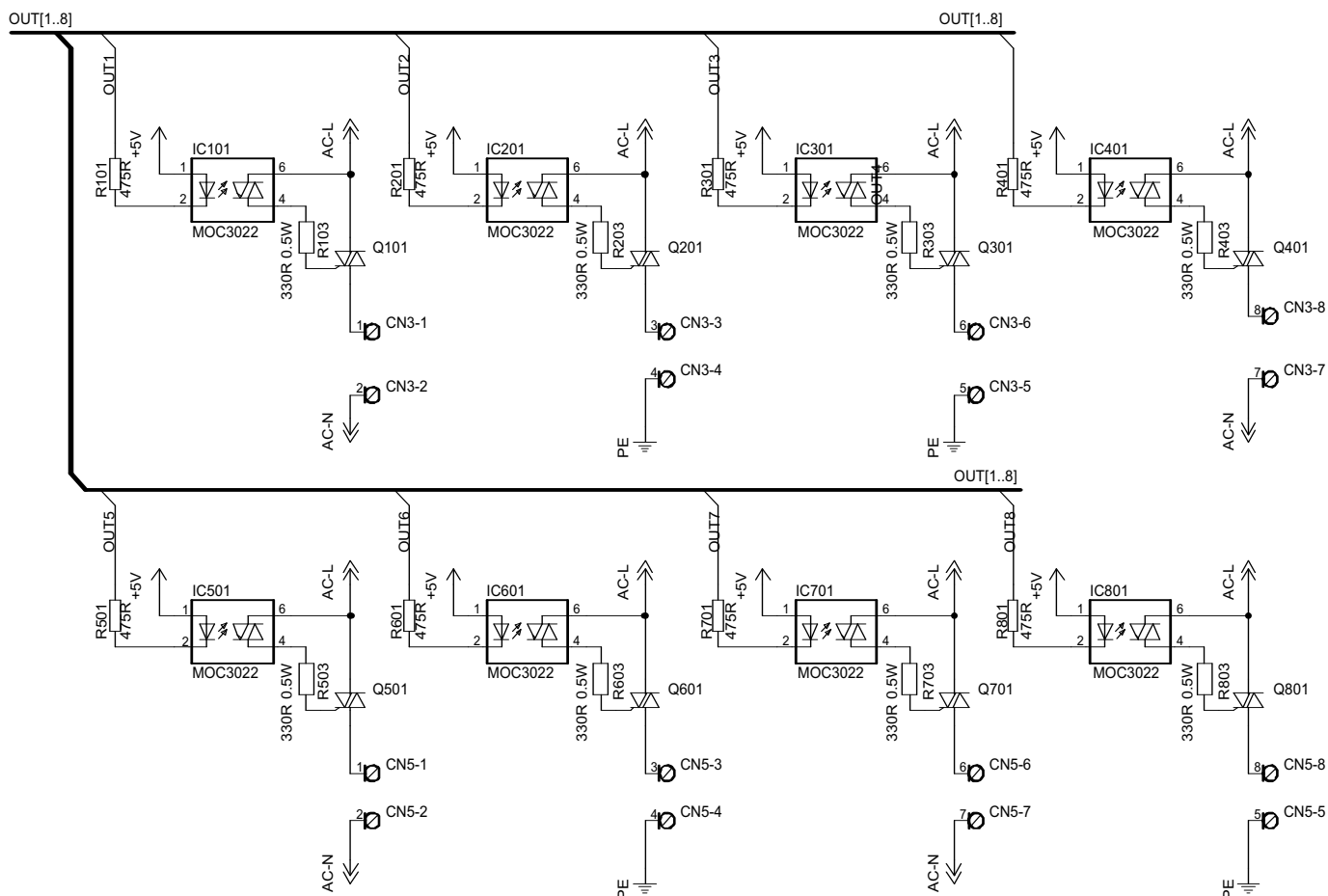
That was the case for two separate problems involving the I²C chips used on version 1 of the I/O PCB. In my

EAGLE library, I have PCF8574P, but in my BOM I have PCF8574A. It turns out that Philips (back before they were called NXP) issued an "A" version with a different base address. I used the A version base address (hex 038) but "non-A" chips are expecting address 20h. Hence, no lights will come on with the wrong chips. The addressing of the two PCF8574 versions are compared in Figure 4.

I received Email about the confusing I/O card address switches. Recall that the four I/O cards are identical but take on a different base address by moving a three position DIP switch. Due to PCB layout restrictions, the LSB of the three digits is on the left, and the switch appears upside down if you follow the "ON" marker on the actual switch. As I wired the switches to ground and ON means closed, we get logic zero at the chip, not logic one. If the switches point to an address outside the range of the controller I²C messages, the lights will never come on. I have redone the silkscreen to save repeating this confusion.

While I was content to "burn" new AVR code for my project, many builders prefer a preprogrammed chip, and have no way of patching the firmware or tweaking it for their needs. I don't mind doing a few of these as a favor to others; it set me to thinking about how to improve the

■ FIGURE 2. MkII schematic, lamp drivers.



The clock display and math are in a 24 hour format, so that am and pm are never confused. Funny story ... once I accidentally set an alarm clock to wake me up at dinner time instead of breakfast! The two BCD encoded data strings (hh:mm) are saved to the EEPROM in the RTC chip: one for start and one for stop. These are converted to minutes and compared to the RTC's clock time (also converted to minutes from its native BCD hh:mm format). When the RTC sum is greater than the start sum, the show runs, and when the RTC sum is greater than the stop sum,

I found that the new AVRISP would reset the target AVR at random and I traced this to noise from my project's 5V rail getting back into the pod. I added a 10K resistor and a 10 μ F capacitor as decoupling, and that did the trick. Unfortunately, those values didn't make it to the published controller BOM, which has the correct six pin header. I got quite a few emails wondering why there was an undocumented C4 and R25 on those new PCBs!

[illegible]

PCF8574 REMOTE 8-BIT I/O EXPANDER FOR I²C BUS

296-13109-5

296-13109-5-ND

PCF8574N

Address Reference

INPUTS			I ² C BUS SLAVE ADDRESS
A2	A1	A0	
L	L	L	32 (decimal), 20 (hexadecimal)
L	L	H	33 (decimal), 21 (hexadecimal)
L	H	L	34 (decimal), 22 (hexadecimal)
L	H	H	35 (decimal), 23 (hexadecimal)
H	L	L	36 (decimal), 24 (hexadecimal)
H	L	H	37 (decimal), 25 (hexadecimal)
H	H	L	38 (decimal), 26 (hexadecimal)
H	H	H	39 (decimal), 27 (hexadecimal)

PCF8574A REMOTE 8-BIT I/O EXPANDER FOR I²C BUS

568-1073-5

568-1073-5-ND

PCF8574APN

Address Reference

INPUTS			I ² C BUS SLAVE ADDRESS
A2	A1	A0	
L	L	L	56 (decimal), 38 (hexadecimal)
L	L	H	57 (decimal), 39 (hexadecimal)
L	H	L	58 (decimal), 3A (hexadecimal)
L	H	H	59 (decimal), 3B (hexadecimal)
H	L	L	60 (decimal), 3C (hexadecimal)
H	L	H	61 (decimal), 3D (hexadecimal)
H	H	L	62 (decimal), 3E (hexadecimal)
H	H	H	63 (decimal), 3F (hexadecimal)

■ FIGURE 4. Addressing scheme.

SMT Techniques

I used a hybrid of through-hole and SMD/SMT (Surface Mount Device/Surface Mount Technology), which turns out to be much easier to construct than you might think if you were raised on through hole-only techniques. While the SMT parts can be hand soldered one pin at a time using a fine tip soldering iron and flux-core solder, I have evolved to a hot air technique. I use solder paste from a syringe to “dot” the SMT pads, place the parts with tweezers, and when the entire side of the PCB is complete I go over it with a hot air gun intended for heat shrink tubing. Violá! The paste turns to molten solder and due to its density forms little puddles centered on the pads while the SMT parts float and snap to the center too, making perfect joints. It’s so much fun to watch! The important lesson here is to only use small amounts of solder paste.

Feedback from builders pointed out that SMT LEDs are really hard to identify, and were often placed backwards. I have edited the EAGLE silk screen to use a diode symbol for my future projects. The cathode (bar) end of the symbol matches the paint dot or stripe on the SMT

LED, but you likely need a 10 power eye loupe to see it. Also, by convention, the LED parts are placed in their carrier tape with the cathode towards the sprocket holes.

User Manual

I deliberately didn’t write operating instructions to go with the first article, as I enjoy discovering how products operate when I’m the customer and use them for the first time. Nothing kills the moment more than having to wade through a thick manual. The Holiday Lights Controller interface is very simple, but just in case you’d like directions I’ve written a brief text file and bundled it with the download for this project from the *Nuts & Volts* website (www.nutsvolts.com).

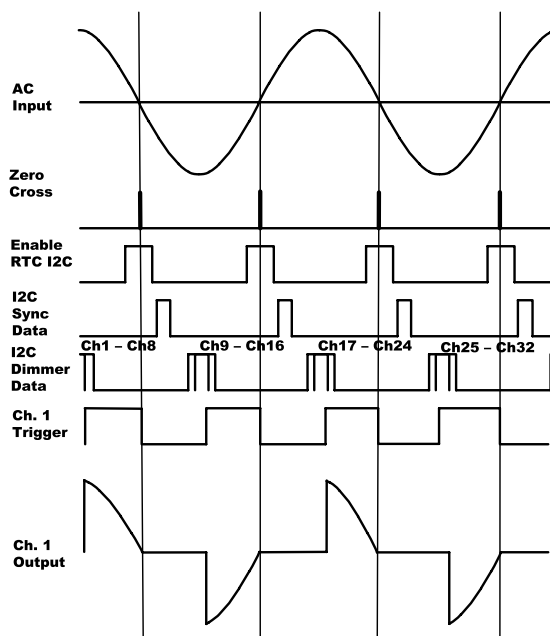
The I/O Card MkII

I have changed the circuitry on the I/O card to use another AVR μ C in place of the fixed function I²C chip, which remains a nice part for other applications.

I²C signals from the controller card still pass along the I²C bus and go to each I/O card which, in turn, has its own base address set by the DIP switches. All cards hear all messages on the bus but only act on those messages directed to a particular card.

The number of messages has been reduced to decrease bus activity – which was the original bottle neck – and rely on the local AVR to set triac phase-angle timing. This way, all channels operate together, removing slight brightness variations from one channel to the next.

Two types of messages are sent: one is the data to be stored for each channel’s dimmer delay and the other message is the AC zero-cross sync. This is sent to all the



■ FIGURE 5. AC and I²C timing diagram.

PARTS LIST - Holiday Lights mk-II Controller

ITEM	DESCRIPTION	Digi-Key PART#
RESISTORS		
<input type="checkbox"/> R1	1.0K 1/4W 1% 1206 SMD	P1.00KFCT-ND
<input type="checkbox"/> R2-R6, R11, R12	10.0K 1/4W 1% 1206 SMD	P10.0KFCT-ND
<input type="checkbox"/> R7-R10	Not used	
<input type="checkbox"/> R101, R102, R201, R202	475Ω 1/4W 1% 1206 SMD	P475FCT-ND
<input type="checkbox"/> R301, R302, R401, R402		
<input type="checkbox"/> R701, R702, R801, R802		
<input type="checkbox"/> R103, R203, R303, R403	330Ω 1/2W 5%	P330BBCT-ND
<input type="checkbox"/> R503, R603, R703, R803		
CAPACITORS		
<input type="checkbox"/> C1	47mF 25V electrolytic SMD	PCE3185CT-ND
<input type="checkbox"/> C3	10mF 16V electrolytic SMD	PCE3062CT-ND
SEMICONDUCTORS		
<input type="checkbox"/> D1	Green LED 1206 SMD	160-1404-1-ND
<input type="checkbox"/> D101-D801	Yellow LED 1206 SMD	160-1406-1-ND
<input type="checkbox"/> IC1	AVR µC (requires programming)	ATTINY261-20PU-ND
<input type="checkbox"/> IC101-801	Optocoupler, triac output	MOC3010M-ND
<input type="checkbox"/> Q101-Q801	Alternistor triac, 400V 8A TO-220AB	Q4008LH4-ND
HARDWARE		
<input type="checkbox"/> CN1,CN2	Vertical header conn 0.100" 10 pos	A26573-ND
<input type="checkbox"/> CN3, CN4	Terminal block, 5mm, horizontal, 6 pos	ED2574-ND
<input type="checkbox"/> CN5	Terminal block, 5mm, horizontal, 8 pos	ED2575-ND
<input type="checkbox"/> CN6	Vertical header conn 0.100" 6 pos	A26569-ND
<input type="checkbox"/> S1	DIP switch, 3 pos, sealed	GH7182-ND
<input type="checkbox"/> F1	Fuse, 250V IEC FA LBC 5X20 5A	F2395-ND
<input type="checkbox"/> N/A (x2)	Fuse clip, 10A 5X20mm PC mount	F063-ND
<input type="checkbox"/> N/A	20 pin IC socket	ED3120-ND

I/O cards when the AC mains voltage has crossed zero. The monitoring LEDs follow the change in brightness of the lamps connected to the output of each channel. To better visualize this idea, see Figure 5.

Different lamp structures have different heating curves due to the mass of their metal filaments. Commercial stage lighting controllers have profiles that are designed for specific lamp types. This is a moot point in a hobby grade holiday lights controller, but worth remembering if your lights seem a little "notchy" upon a slow fade up or down.

The AVR µC on each I/O card requires its own firmware, so the MkII I/O card has a six pin header for programming. As it's only needed once, it can be left off the PCB, or use pre-programmed AVR chips and install a 20 pin DIP socket.


Holiday Wrap-Up

I hope this article was informative, even though we rehashed details from a year ago. I like to improve projects and correct problems as they crop up so I have been busy with my original Holiday Lights Controller design along side the new one. This year,

we're dazzling the neighborhood, and if you drive by, please enjoy the show! **NV**

Have a question?

Please contact the author via email at pstonard@ix.netcom.com. Or, join us on-line at the *Nuts & Volts* forum. (www.nutsvolts.com)



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by Marvin Mallon

THE ALTOIDIMETER

Do you wonder what altitude your model Cessna made it to on that last flight? Need to know how high up the face of Half Dome you've climbed? Wonder how far down it is to the swirling Pacific as you hang glide over Torrey Pines?

Sounds like you're a candidate for a Zlog miniaturized recording altimeter.

This intriguing device is the brainchild of Matt Woolsey, sole proprietor of Hexpert Systems located in Grass Valley, CA. Principally created as an accessory for hobbyists engaged in model aircraft flight, the concept of a recording altimeter lends itself to a number of applications. This article explores how it works and how it can be adapted to your own project.

The fully assembled unit weighs only eight grams and measures 1.57" x 0.92" x 0.37" or in metric terms, 40 mm x 23.4 mm x 9.4 mm. The device is a stunning example of state-of-the-art electronic miniaturization. It was designed to provide a lightweight, compact device for measuring and recording altitude over time. It is specifically for use onboard a radio controlled (R/C) aircraft, but should be useful in other applications, as well. ZLog provides live altitude information in the field via its self-contained digital display, and recorded altitude data through a USB interface.

How It Works

The ZLog module uses a high-resolution barometric pressure sensor system to detect the minute changes in air pressure that occur due to changes in altitude. It is sensitive enough to detect altitude changes of less than one foot. Since it is so sensitive, it is also subject to changes in weather and local pressure variations. Long-term altitude readings

will vary considerably due to varying atmospheric conditions. It is best used to measure relative changes in altitude. Key features include:

- Displays altitude information in real time.
- Tracks maximum altitude.
- Records altitude data for later review.
- USB PC interface built in for configuration and data download and review.
- Local controls allow configuration in the field.
- Records altitude either periodically or when triggered from an external signal.
- Firmware upgradeable.
- Weighs only eight grams.

The host system requirements are:

- A PC with Win98, Windows ME, Windows NT, Windows 2000, or Windows XP.
- CD-ROM drive.
- USB port.
- Two megabytes hard drive space.

Figure 1 shows the ZLog module. Two pushbutton switches are used to configure the device and to select either a current or maximum altitude display. A three-pin connector connects to the model aircraft's onboard receiver to obtain power, but for non-R/C use a battery can be attached to the servo pass-through connector. Input voltage can range from 3.7 to 30 volts DC. Current drain is only 13 milliamps. The backlight

draws another three milliamps. The unit operates over a temperature range of 0° C to 60° C. Within this range, the pressure sensor has an accuracy of $\pm 1.5\%$ of its measured output to the microcontroller. If the temperature dips to -10° C, the accuracy is reduced to $\pm 3.0\%$. These deviations are non-linear and are dependent on altitude.

The unit can operate up to 52,000 feet but will only display 9,999 feet, yards, or meters. The recorded data permits altitude readings to a maximum of 32,767 feet. Conversely, the minimum absolute altitude for operation is $-2,000$ feet. This figure is academic since the device is hardly waterproof, but if taking a reading at the bottom of the Mariannis Trench is your thing, then attach it outside your bathysphere next time you go diving.

At that level, it will display -999 feet/yards or meters and record (either relative or absolute) up to $-32,512$ feet. Negative altitude range is required to measure altitude in low-pressure zones (e.g., in a storm). Water pressure increases much faster with depth than does air pressure. Either above or below sea level, the unit has an altitude resolution of one foot (or one meter, whichever is the chosen measure). These parameters are summarized in Figure 2. Figure 3 is a block diagram of the ZLog unit. Here are descriptions of each section:

- *Integrated Pressure Sensor* — Silicon micro-machine sensor with integrated signal conditioning, amplification,

linearization, and temperature compensation. Outputs a signal proportional to air pressure.

- **16-bit Analog-to-Digital Converter** – Transforms the analog info from the sensor into the necessary digital representation for further processing by the microcontroller.

- **Microcontroller** – Eight-bit 8051 with onboard Flash and RAM. Reads the A/D, calculates altitude from pressure, displays the altitude, and records to EEPROM (electronically erasable programmable read-only memory).

- **LCD Display** – Four-digit LCD with inter-integrated circuit interface.

- **32K EEPROM** – For storing recorded altitude data.

- **USB/Serial Converter** – Interface to PC or external microprocessor for configuring, reading/writing altitude data, logging real-time altitude, etc.

- **Buttons** – Allow user to configure the altimeter setup using the LCD.

- **LEDs** – Indicate USB link, power, recording on, and flashes with each sample.

- **Voltage Regulator** – Converts input voltage to regulated 3.3V for the system. Takes input either from the USB port if attached or an external battery (or R/C receiver channel).

Figure 4 is a representation of the placement of all of these components.

Operation

The module operates in one of three modes, depending on the position of the pushbutton switches at startup. These modes are shown in Table 1.

Normal Mode

Normal mode is how the module will be used most of the time. In this mode, the module continuously displays altitude. The display updates four times per second. Note that this does not necessarily correlate to the sampling period. The following controls are available in normal mode:

- **Current/Maximum Altitude Select** – Toggles the display between current

Dimensions	1.57" x 0.92" x 0.37" 40 mm x 23.4 mm x 9.4 mm
Weight	Eight grams
Temperature Range¹	0°C–60°C (pressure sensor ±1.5% accuracy) -10°C–60°C (pressure sensor ±3.0% accuracy)
Input Voltage Range	4.0–30.0 volts DC
Input Current	16 milliamps (backlight on). 13 milliamps (backlight off).
Maximum Altitude¹	Measured: 52,000 feet (15,849 meters) Displayed: 9,999 feet/yards/meters Recorded: 32,767 feet (9,987 meters)
Minimum Altitude¹	Measured (absolute): -2,000 feet (-656 meters) Displayed (relative or absolute): -999 feet/yards/meters Recorded (relative or absolute): -32,512 feet (-9,909 meters)
Memory Capacity	16,378 samples
Acquisition Sampling Rates	100 milliseconds/sample up to one hour/sample in 100 millisecond increments
Timing Accuracy	±2.5%
Altitude Resolution	One foot (one meter)
¹ Specifications taken from component ratings and system limits; may not have been tested to the full extent of the specified ranges.	
■ FIGURE 2	

altitude and maximum altitude.

The display differentiates the two by flashing the maximum altitude. The maximum altitude is the greatest altitude recorded since the module was turned on.

- **Zero Altitude** – The current altitude to be set as the zero point with all subsequent readings being relative to that point.

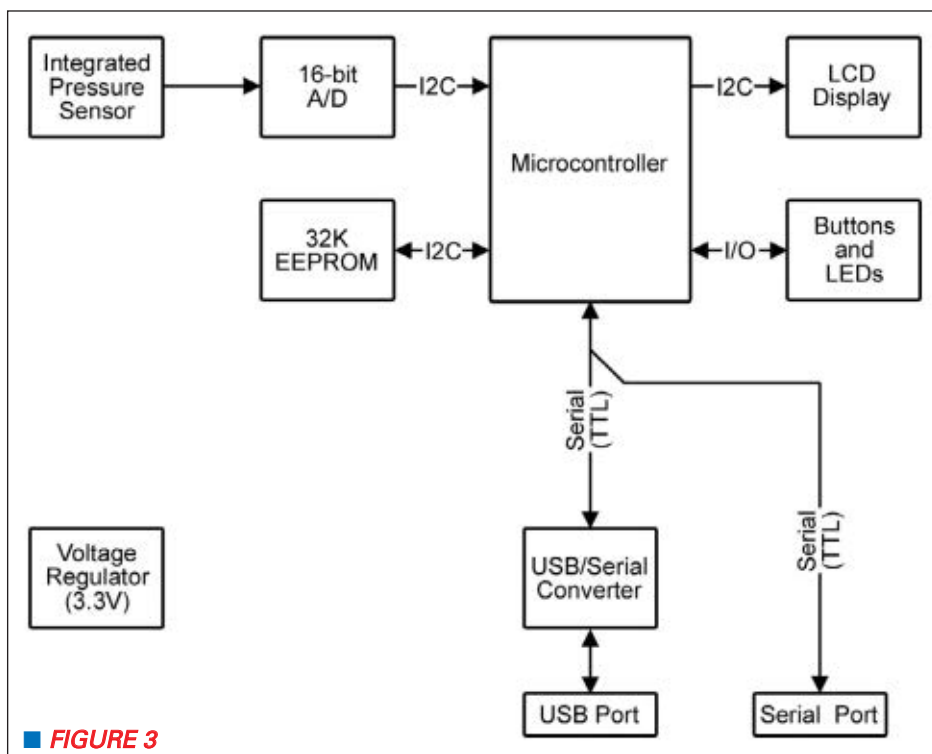
- **Recording Start/Stop** – Store altitude data in memory. The number

of data sets is limited only by the amount of free data storage memory available.

Config Mode

Config mode allows the module to be configured using the two pushbuttons.

- **RATE** – This option selects the sampling period.
- **CLR** – This command clears



■ **FIGURE 3**

the data memory.

- NIT – This option selects the altitude units.
- LITE – This option selects whether the display backlight is off or on.
- TRIG – This option selects whether external trigger recording is off or on.
- TREV – This option selects normal or reversed action for the servo-triggered altitude capture.
- STRT – This selects between auto-start recording options.
- STOP – This selects between auto-stop recording options.
- ZERO – This selects between auto-zero altitude options.
- BAUD – This command changes the baud rate that ZLog uses to communicate with the PC or other electronics.
- DFLT – This command resets the configuration values to defaults.
- SAVE – This command will save the changed parameters.
- RST – This command will reset the module.

Program Mode

Programming mode allows new firmware to be loaded into the ZLog module through the PC interface.

- *PC Interface* – The PC USB cable connects to the ZLog module's USB Mini-B connector. When connecting the USB cable, the ZLog module is also powered through the USB port.
- *PC Software* – Permits the downloading of the latest software and USB drivers.

Figure 5 represents a typical Altitude versus Time readout as recorded when the ZLog altimeter captures flight data. Other scaling would produce similar information if you were hang gliding, skiing down your favorite slope, and in any other circumstance where altitude varies with time.

It's important to note the difference between Absolute

Mode	Startup	Display	Description
Normal	S1 not pressed S2 not pressed	Altitude	Normal operating mode – Displays altitude; interfaces with PC.
Config	S1 pressed S2 not pressed	"Cfg"	Configuration mode – Used to configure the module via the pushbuttons.
Program	S1 not pressed S2 pressed, or initiated by firmware update from PC software	"Prog"	Program mode – Used to put the module into a programming mode for loading new firmware updates to the module. Don't use this module until specifically instructed to do so by the PC application software during an update.

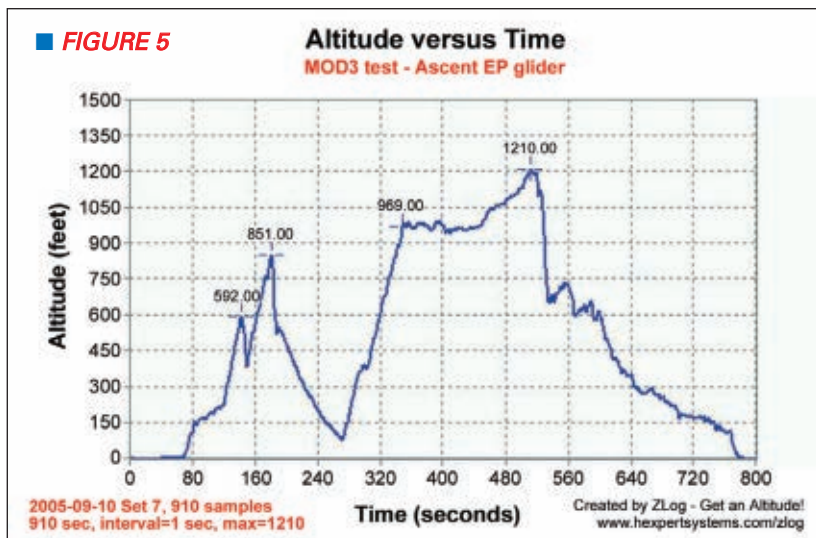
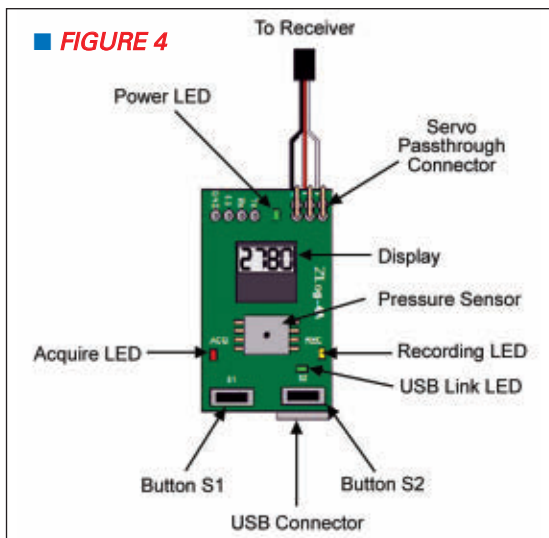
■ **TABLE 1**

and Relative altitude. Absolute, of course, refers to your height above sea level. This reading on the ZLog device could be off by as much as a few hundred feet due to varying atmospheric conditions. Barometric pressure changes caused by approaching storms, etc., influence the accuracy of any altimeter when attempting to make this reading. That's why pilots get a specific reading from the control tower prior to take-off.

Relative altitude is a measure of the change in height from a previously reset base altitude. For most applications, this is quite sufficient. If you make Katmandu your starting point, then you know you only have another 24,535 feet to go to reach the top of Everest. Don't forget to bring fresh batteries.

Building the Altoidimeter

Matt kindly volunteered a unit and, after a little experimentation, I found that it and a nine volt battery fit nicely into an Altoids box (Figure 6). Using self-adhesive hook and loop strips, I fastened the battery to the inside upper third of the container. Figure 7 shows how snugly it fits and yet can be removed easily for a battery change.



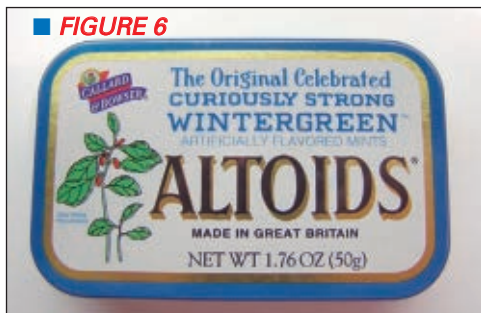


FIGURE 6

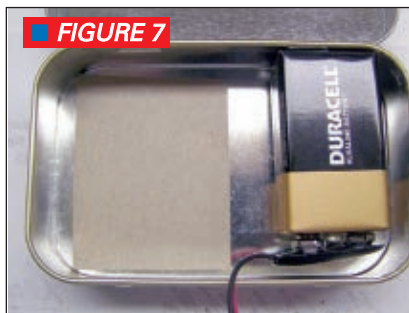


FIGURE 7

Next, I glued down a piece of cardboard to act as an insulator against shorts when the ZLog unit is mounted.

The unit (as supplied) does not have an on-off power switch, so I improvised one by mounting a miniature slide switch (see Figure 8) and cut the positive lead of the battery adapter connector and soldered it as shown. Any small SPST found in your junk box will do. The switch was permanently super glued in place since replacement seems unlikely. Next, I slid the ZLog unit in place. It fit snugly without rattling around but still permitted removal for hookup to a PC using the USB cable that Matt supplies. Voilà! You have just constructed your own personal Altoidimeter.

Operation

In operation, the lid of the box is opened, the power switch is thrown, and the miniature LED indicates that you are on the air. S1 and S2 are pressed simultaneously to zero the display. You are now ready to read relative altitude. The package works just fine with the cover closed

since there is enough of an opening at the hinges to guarantee that the air pressure inside the box is the same as outside.

How about some peculiar, but informative applications, such as:

- Take it on your next roller coaster ride and get a readout on just how high the Blue Monster took you. Plug the unit into your PC and get a graph of time versus altitude for that bit of excitement. Don't be surprised if the chart looks like a spread out display of the peaks and troughs of the track layout.
- Get a read on how high your model rocket ascended. A bit more cushioning would seem prudent since hard landings are a common occurrence. You'll want to put it into its maximum altitude mode.
- Somebody gave you a gift certificate for that balloon ride you always wanted to take? Great! The Altoidimeter is the perfect companion for the trip. I drifted lazily in one of those hot air bags over Perris, CA one cool desert morning but had no idea how high we climbed. The onboard LCD display would have come up with the answer. **NV**



FIGURE 8

RESOURCES

A visit to Matt's website at www.hexpertsystems.com will furnish further information about this and other products of his. Lists of dealers who handle these devices, as well as entry to his online store are also available. An email to him will get a speedy response. You can inquire about purchasing a completely assembled unit or just a subset of the device such as the circuit board only, the pressure sensor, the LCD display, or possibly other components should you wish to incorporate the functionality of the unit into your own project.

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SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

PART 4: Teaching a Butterfly to Talk

Get started now with this series! Joe's book & kit are available in our webstore at www.nutsvolts.com

This month, we are going to learn some more C syntax, a bit about libraries, and teach your Butterfly to talk. Now that you've gotten hooked on learning C for the AVR, I want to admit to some trepidation about how this stuff should be taught.

Most people like my method that gets you started blinking LEDs and reading switches without fully understanding all the code you are using. I tell folks to be patient and that some of the weird stuff will eventually start to make sense. This is how I learned C. I copied lots of code, bent it to fit my needs, and then read

about the stuff I didn't understand. This worked for me, but it isn't a formal handholding, spoon-feeding process like some folks seem to want. Frankly, if you really need that, then you should think hard about messing with microcontrollers or programming, since this is a wild and chaotic milieu through which there is no royal road. You have to do a lot of work and can count yourself lucky to get an experienced guide.

Another issue is that at the rate we are going, mixing in projects and asides like this one, it will take us nearly a year to work through the C language syntax. This is a good thing

■ **FIGURE 1.** PC communicating with Smiley's Workshop Learning Platform.



in that it gives us plenty of time and lots of microcontroller-related examples, but it's a bad thing since most folks can learn the syntax a lot faster if they so choose. For those who wish we'd move things along a bit faster, I want to suggest that you get the shareware Pelles C compiler at www.smorgasbordet.com/pellesc/ and then purchase the venerable *The C Programming Language* by Kernighan and Ritchie. That way, you can zip along learning C syntax at your own rate and use this workshop to review in the context of AVR microcontrollers.

Some More C Syntax

Assignment Operators Relational Operators

Operators seem like ordinary arithmetic or algebra symbols, and they mostly are. But they are different often enough that you need to pay attention when operations don't act

Operator	Name	Example	Defined
*	Multiplication	x*y	Multiply x times y
/	Division	x/y	Divide x by y
%	Modulo	x%y	Provide the remainder of x divided by y
+	Addition	x+y	Add x and y
-	Subtraction	x-y	Subtract y from x
++	Increment	x++	Increment x after using it
--	Decrement	--x	Decrement x before using it
-	Negation	-x	Multiply x by -1
+	Unary Plus	+x	Show x is positive (not really needed)

TABLE 1. Arithmetic Operators.

Operator	Name	Example	Defined
>	Greater than	x>y	1 if x is greater than y, otherwise 0
>=	Greater than or equal to	x>=y	1 if x is greater than or equal to y, otherwise 0
<	Less than	x<y	1 if x is less than y, otherwise 0
<=	Less than or equal to	x<=y	1 if x is less than or equal to y, otherwise 0
==	Equal to	x==y	1 if x equals y, otherwise 0
!=	Not equal to	x!=y	1 if x is not equal to y, otherwise 0

TABLE 2. Relational Operators.

like you think they should. An example of the kind of confusion you can run into is when you use the '=' assignment operator and the '==' 'is equal to' operator:

```
x = y;
if(x==y) _delay_loop_2(30000);
```

The first statement assigns x the value of y. The second statement calls the _delay_loop_2(30000) function if x 'is equal to' y. What about:

```
if(x=y) _delay_loop_2(30000); //BAD STATEMENT
```

This will set x equal to y and then call the _delay_loop_2(30000) function. The 'if' is checking to see if the statement is true, meaning that it is not equal to 0. In our case, the delay will always run unless y is 0, then it will never run. Either way, it isn't what you thought you were testing. The WinAVR compiler will think something is strange and issue this warning:

Warning: suggest parentheses around assignment used as truth value which will scroll by so fast you won't see it, so you'll assume the compile was good. It is a very easy mistake to make, and you will feel really dumb after an hour of debugging, looking for something obscure, only to find a lousy missing '=' character. I do this all the time.

Assignment Operators

The assignment operators provide a kind of shorthand technique for arithmetic operations. The following statements are equivalent:

```
myByte = myByte + yourByte;
```

Same as:

```
myByte += yourByte;
```

Conditional Expressions

You will frequently need to make decisions based on external conditions. For example, if the temperature is above 150° F turn the fan on, otherwise turn the fan off.

You could write this as:

```
if( temp > 150 )
    turnFan(ON);
else
    turnFan(OFF);
```

Or, you could use the C conditional operator ?: as below:

```
temp > 150 ? turnFan(ON) :
turnFan(OFF);
```

The operation has the form expression1 ? expression2 : expression3, and follows the rule that if expression1 is true (non-zero value), then use expression2, otherwise use expression3. This operator seems a little gee-wiz-impress-your-friends and not as clear as the if-else expression, but you'll see this a lot so get used to it.

Precedence and Order of Evaluation

When a statement has a sequence of operators such as:

```
x = 50 + 10 / 2 - 20 * 4;
```

the compiler follows an order of calculation based on operator precedence. But what the compiler does may not be what you intended. Calculate the value of x. Did you get 40? If you performed the calculations sequentially beginning at the left, you get:

```
x = 50 + 10 / 2 - 20 * 4
x = 60 / 2 - 20 * 4
x = 30 - 20 * 4
x = 10 * 4
x = 40
```

So the answer is 40, right? Wrong, according to C, it is -25. The compiler does the division and multiplication first, then the addition and subtraction:

```
x = 50 + 10 / 2 - 20 * 4
x = 50 + 10 / 2 - 80
x = 50 + 5 - 80
x = 55 - 80
x = -25
```

Some C gurus will memorize the precedence and associativity table and actually write statements like x = 50 + 10 / 2 - 20 * 4. Such clever programmers are dangerous and should be avoided when possible. The Germans have a word for clever: kluge. And in programming, 'kluge' is a well-deserved insult.

Don't be clever, be clear. Clever programming is difficult to read and understand. If the clever programmer gets run over by a truck (hopefully), his code will be inherited by some poor guy who will have to figure things out. DO NOT memorize the Table of Operator Precedence and Associativity in C (which I refuse to even show). DO use '(' and ')' to make your program clear!

Which is clearer:

```
x = 50 + 10 / 2 - 20 * 4;
```

or :

```
x = 50 + (10 / 2) - (20 * 4);
```

The second adds nothing for the compiler, but tells the reader what

Operator	Name	Example	Defined
=	Assignment	x=y	Put the value of y into x
+=	Add	x += y	Compound assignment provides a short cut way to write an expression, for example: x += y; is the same as x = x + y; x /= y; is the same as x = x/y;
-=	Subtract	x -= y	
*=	Multiply	x *= y	
/=	Divide	x /= y	
%=	Modulo	x %= y	
<<=	Left Shift	x <<= y	
>>=	Right Shift	x >>= y	
&=	Bitwise AND	x &= y	
^=	Bitwise XOR	x ^= y	
=	Bitwise OR	x = y	

TABLE 3. Assignment Operators.



you intended. What if you really meant to have the operations performed in the order listed? Then you would write:

```
x = (((50 + 10) / 2) - 20) * 4;
```

which would make $x = 40$. The parentheses can get mighty confusing, but not nearly as confusing as their absence.

Getting Started with C Libraries

Libraries: avr-libc library

Software libraries are repositories of functions that have been precompiled and stored as object modules that the compiler/linker can find and put into the code when you want to use them. These library functions are defined in a header file (filename ends with an .h suffix), usually with the same name as the library and have some documentation that tells you how to use the function (avr-libc-user-manual.pdf which you can find at the unlikely location C:\WinAVR-20071221\doc\avr-libc\ if you followed instructions and installed WinAVR in the default location). You saw an example of a header file in PortIO.c from Workshop 3:

```
// PortIO.c
#include <avr/io.h>
```

Also, we are talking a lot about functions here and haven't really addressed what a function is yet other than the cursory preview given in Workshop 2. We won't get into details for a few Workshops, but briefly, a function encapsulates a computation; it may return a value and it may require input parameters.

The really great thing about library functions is that you don't have to know how they do their job and you never have to look at the code that does it. In object-oriented programming, this concept is called encapsulation and carries with it the idea that the less you can get your hands on, the less you are likely to

screw up. Now as insulting as that may seem, it is nonetheless a very good software engineering principle. If it works and you can't get at it, then you can't break it.

Let's apply this by using the library libsmws4.a to get the Butterfly shouting some math at the PC. This library will do things in the background that will allow you to send and receive data over the UART without having to know a thing about how it works.

We will also use two standard C libraries: stdio and stdlib. From stdio, we will use the standard C function printf() and a special AVR modified function printfP(PSTR()) which allows us to store strings in Flash memory which we have a lot of rather than RAM (which we have much less of). From stdlib, we will use atoi() to convert an ASCII string to an integer. Look at these functions in the avr-libc manual and try not to freak out too much over the complexity since our job here is to learn enough over time so that the manual will make sense, eventually, more or less.

Is Anybody Out There? Communicating With a PC

Most microcontrollers are buried deep in some device where they run in merry isolation from the rest of the world. Their programs are burned into them and never change. But there are many instances when we might want to communicate with a microcontroller, this being one of them. The Butterfly uses a joystick and an LCD, which is fine for its built-in menu based applications. For anything more complex — like changing the microcontroller software — nothing beats using the PC's serial communications port to communicate with the microcontroller.

What we need is a method to send commands and data from the PC and receive responses from the Butterfly. In this section, we will develop a generic command interpreter skeleton that we will reuse

in later programs. In this project, we will use this skeleton to build a demonstration that lets the PC ask the Butterfly to do some simple math. Hey, bet you never thought you'd be training a Butterfly to add, subtract, multiply, and divide!

Writing MathCommunicator.c

Let me repeat: The MathCommunicator files we are about to use have many things in them that are well beyond our C training at this point, so just use them and don't think too hard about it yet. We will revisit each function in later Workshops as we increase our knowledge.

Before creating the MathCommunicator project in AVRStudio, read the Smiley's Workshop 4 – Supplement: *Adding Libraries to Projects* pdf file that you can get from *Nuts & Volts* (www.nutsvolts.com) or Smiley Micros Workshop4.zip download that also contains the AVRStudio project.

```
#include <avr/io.h>
#include <stdio.h>
#include <stdlib.h>

// include the special library
// for Smiley's Workshop 4
#include "smws4.h"

// define the parseCommand
// function
void parseCommand(char *,
uint8_t);

int main(void)
{
    char b = 0;
    char s[6];
    uint8_t count = 0;

    // this is in libsmws4
    initialization();

    // the _P and PSTR weirdness
    // allows you to store a
    // string in flash rather than
    // wasting space in SRAM
    printf_P(PSTR("Math
Communicator at your serv-
ice!\n"));

    while(1)
    {
        while(b != '\n')
        {
            // this is in smws4.a
            b = (char)receiveByte();
            s[count++] = b;
        }
    }
}
```



```

    parseCommand(s, count);
    b = 0;
    count = 0;
}

    return 0;
}

void parseCommand(char
*s, uint8_t cnt)
{
    int a,b;
    char t[3];

    t[0] = s[0];
    t[1] = s[1];
    t[2] = 0;
    a = atoi(t);
    t[0] = s[3];
    t[1] = s[4];
    t[2] = 0;
    b = atoi(t);

    switch (s[2])
    {
        case '+':
            printf("%d + %d =
%d\n", a,b,a+b);
            break;
        case '-':
            printf("%d - %d =
%d\n", a,b,a-b);
            break;
        case '/':
            printf("%d / %d =
%d\n", a,b,a/b);
            break;
        case '*':
            printf("%d * %d =
%d\n", a,b,a*b);
            break;
        case '%':
            printf("%d %% %d =
%d\n", a,b,a%b);
            break;
        default:
            {
                printf_P(PSTR("Say
what?\n"));
                break;
            }
    }
}

```

The `parseCommand(char *s, uint8_t cnt)` is really going to challenge my 'be patient, you'll learn what this all means later' admonition. I considered just sticking it in the library so you wouldn't be blinded by it, but this will all make sense eventually so, like I said, be patient.

Using MathCommunicator.c

We will demonstrate this code using the Developer Terminal that you were introduced to in Workshop 1.

In order to make our life simpler, we will restrict our math to

two digit integers. We will also tell the Butterfly that the communication is finished by sending an equal sign '='. We will send a digit as exactly two characters and if the digit is only one character, we will precede it with a 0; also, we will use no spaces. For example:

Add:	01+01=
Subtract:	02-01=
Divide:	50/05=
Multiply:	25*05=
Modulus:	99%05=

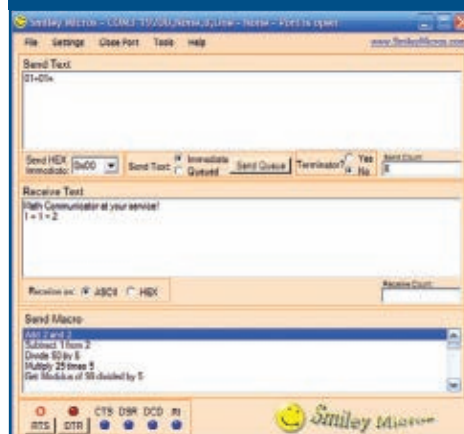
To help you with this, there is an XML data file: `MathCommunicatorXMLData.xml` in `Workshop4.zip` file that includes some examples of each math function used. In Developer Terminal, open the 'File' menu then select 'Open XML Data' and browse to the same directory as the `MathCommunicator` source code.

Next month, we'll look at some more C syntax and learn that there are exactly 10 types of people in the world: those that understand binary and those that don't. And, yes, that will make sense after you've read the article. **NV**

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■ **FIGURE 2. Developer Terminal with Math Communicator XML data.**



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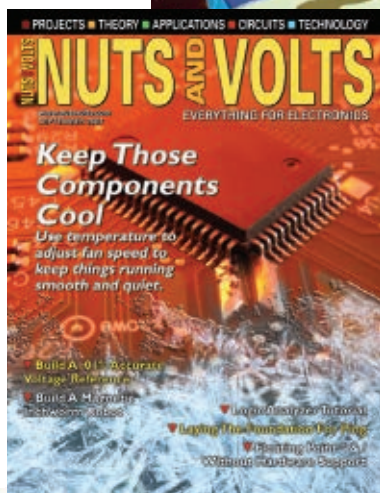
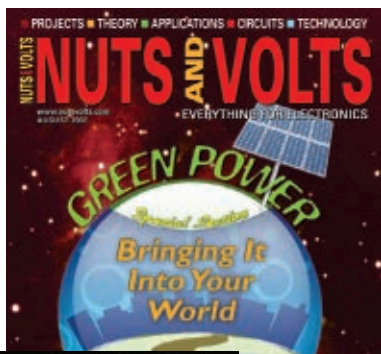
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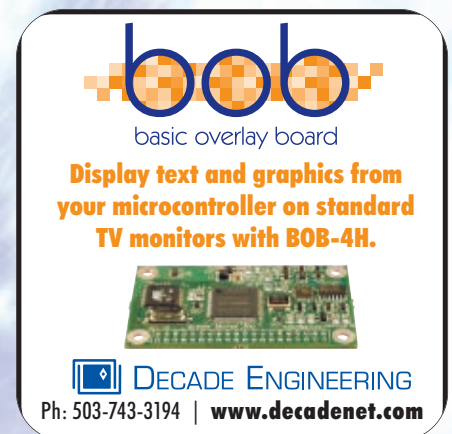
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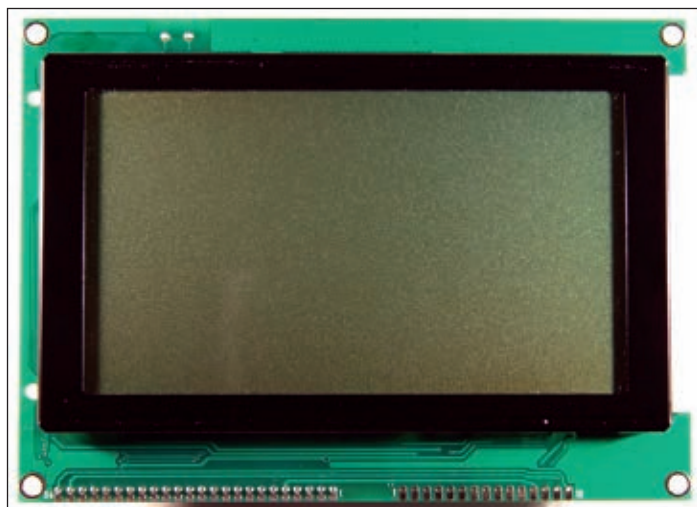
MOVING PAST THE 2X16 LCD DISPLAY

Does your microcontroller project need to convey a bit more information than a standard 16 x 2 LCD can handle? If so, one of the best ways to establish a data communications session between a microcontroller-based device and human eyes is to pipe the human-to-device and device-to-human chatter through an RS-232 connection that you establish between the microcontroller's USART and a personal computer's serial port.

In most cases, a typical RS-232 terminal emulator application running on a PC provides an infinite textual palate for the microcontroller. If the terminal emulator application has the ability to mimic an industry standard VT-100 terminal (TeraTerm Pro does), you (the embedded device programmer) can call upon the VT-100 command set to easily manipulate the position of the microcontroller-generated text that is displayed in the terminal emulator window. As long as there is not a requirement for the display of graphical information, the RS-232 terminal emulator-to-microcontroller lashup works very well. In fact, you've seen RS-232 embedded device hookups like the one I've just described work for us many times in previous Design Cycle discussions.

Most successful microcontroller-based embedded

■ **PHOTO 1.** My first impulse was to purchase a raw LCD panel and mix up the LCD controller hardware from scratch. However, performing a scratch LCD controller build also includes a scratch LCD controller firmware build. The Matrix Orbital GLK240128-25 has more than adequate firmware and application support behind it, which erases the reasoning for scratch-designing LCD controller hardware and firmware.



devices either lead lonely lives in the field or stand at a constant vigil performing real time monitoring and control duties. As far as the set-and-forget embedded devices are concerned, it's normally not a problem to whip out your laptop and spawn an ad-hoc conversation with the device's on-board microcontroller. If the embedded device is working full time at communicating real time information to humans, a dedicated laptop running a terminal emulator may not necessarily be the ideal human-to-machine interface. Using a laptop in this manner is expensive and normally requires a separate laptop power source and a reserved piece of laptop real estate.

If you have a microcontroller application that requires the flexibility and large textual area of a laptop terminal emulator, there is a cheaper, smaller, and less power-hungry alternative: a ready-to-run-out-of-the-box Matrix Orbital GLK240128-25 LCD panel.

ONE BIG LCD

My "thing" includes soldering irons, microcontrollers, and C compilers. Arranging a bunch of pixels into something the mind's eye sees as a recognizable image is not something I lay awake at night planning to do. However, if you're artsy, the GLK240128-25 offers a relatively large dot-addressable canvas of 240 x 128 pixels. For folks like me that only use Microsoft Paint to view bitmap images, the Matrix Orbital LCD panel has built-in functionality that manages fonts and bitmaps while making us art-challenged geeks look really talented at the same time.

The GLK240128-25 is a large, intelligent LCD panel that interfaces to almost anything that can speak RS-232 or I²C. The one we will be working with can be seen in Photo 1. We'll communicate with our panel using a 19,200 bps RS-232 link, which happens to be the default RS-232 baud rate.

The hardware is equipped with a 128 byte receive buffer, which allows the GLK240128-25 to communicate

at a maximum speed of 115,200 bps using RS-232 and 400 Kbps utilizing the I²C protocol. An industry standard RS-232 interface IC converts the AVR USART TTL signals to EIA levels. The panel also allows the AVR USART to speak directly with another microcontroller USART using TTL signals only. The selection of RS-232, TTL, or I²C communication links falls under the control of the Protocol Select Jumpers. As you can see in Photo 2, the panel is jumpered for RS-232 operation.

The firmware contained within the ATMEL AVR microcontroller provides programmatic control of the fonts, backlight, and contrast. The GLK240128-25 also features a 25-key matrix keypad interface. A quick look at Photo 3 shows us that the communications and power interconnects can terminate at either a standard nine-pin D-shell connector or at a four-pin diskette drive power interface.

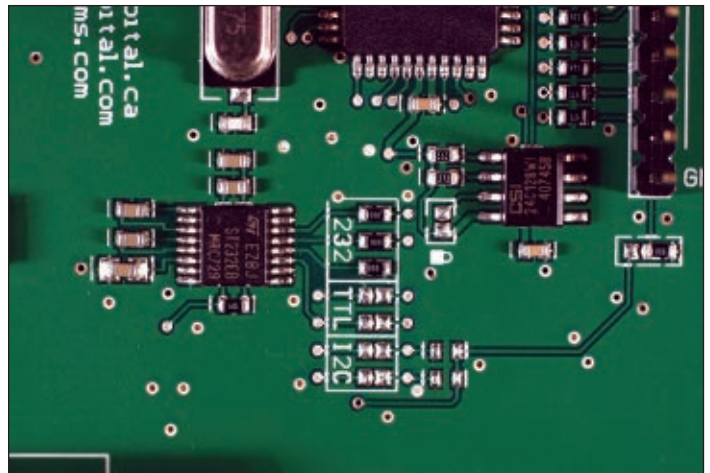
Multiple power supply voltage levels are available and depend on the model you order. The hardware you see in Photo 3 includes an optional voltage regulator that allows operation between 7 VDC and 15 VDC (V model). Models that operate at 5 VDC are standard with a higher voltage model variant (VPT model) available that can operate at voltages up to 35 VDC.

The use of the four-pin diskette interface and the nine-pin D-shell connector as power inputs is mutually exclusive. A jumper must be installed to allow power to flow into the panel via pin 9 of the nine-pin D-shell connector. The controller circuitry will typically draw about 31 mA. If you use the integral backlight, plan on supplying an additional 160 mA of current.

Look again at Photo 2. The keypad matrix interface — which consists of a column of pins — is located just to the right of the AVR ATMEGA164 microcontroller. We can employ a single key or mix and match any number of keys up to the maximum number of keys the 25 key (5 x 5) matrix will physically handle. The output character of each key is programmable. All we need to do to use the keypad feature with RS-232 is simply short a row pin to a column pin. The character associated with the row and column short will be transmitted from the RS-232 TX line. If we lose our way, or the GLK240128-25 goes bonkers, shorting the row 5 and column 1 pins will reset the unit to factory defaults. In that the panel “remembers” user settings via the save command, the factory default values must be saved in order for the factory default settings to become the configuration settings at the next power-up.

I would venture to guess that the GLK240128-25's 128 byte communications buffer is located within the AVR's internal SRAM. The user manual states that there is a 16 KB chunk of bitmap and font space available to the user. When converted to bits, 16 KB is equivalent to 128

■ **PHOTO 3.** Note that the PC diskette drive power connector is not wired as a standard PC connector. Also, the nine-pin D-shell connector and the four-pin diskette drive connector cannot be used simultaneously. A jumper must be installed to allow the Matrix Orbital GLK240128-25 input power to flow through the nine-pin D-shell connector. The optional voltage regulator is mounted just above the data and power interface connectors.



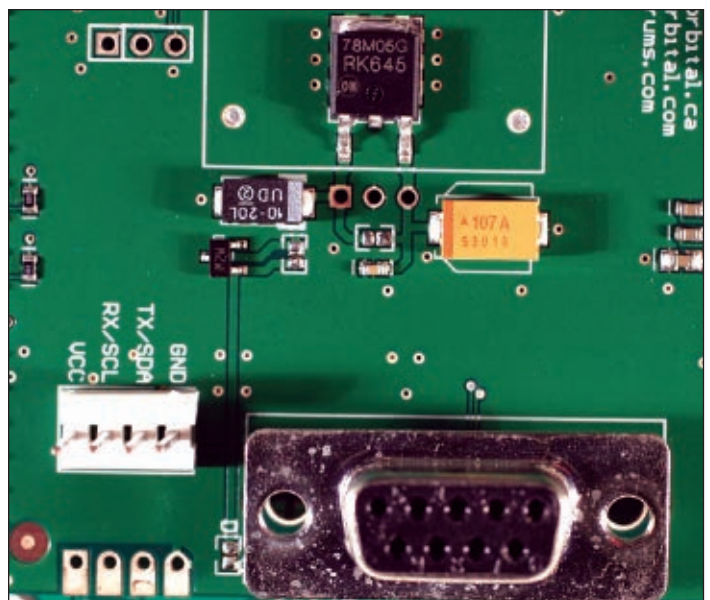
■ **PHOTO 2.** An extended temperature range STMicroelectronics ST232EB RS-232 interface IC is just to the left of the Protocol Select Jumpers. A Catalyst Semiconductor 128-Kbit I²C Serial CMOS EEPROM sits to the right of the Protocol Select Jumper area. The AVR in command is an ATMEGA164. I suspect that the bitmaps and fonts are kept within the EEPROM, as 128 Kbits equates to the 16 Kbytes of bitmap and font memory the Matrix Orbital GLK240128-25 claims to contain.

Kbits. The Catalyst Semiconductor 24C128WI I²C CMOS EEPROM just happens to be a 128 Kbit device. Hmmm

...

As for the panel's configuration bits, they can either be stored in part of the ATMEGA164's internal EEPROM or blasted into a reserved portion of the ATMEGA164's program Flash. There may even be just enough byte area within the EEPROM to squeeze in the configuration data.

In the grand scheme of things, where and how the LCD panel stores the configuration and graphical data doesn't matter to us. All we care about is that the storage areas exist and are available to us. With that, limber up those fingers and let's stuff some configuration bits, graphical code, and data into those special-purpose memory blocks we've just discussed.



I.C. PIXELS!!

We are about to embark on a detailed tour of the C code that is necessary to instruct a Matrix Orbital GLK240128-25 to emulate the display end of a PC terminal emulator application. The code I will reveal to you was written and compiled for a PIC18F2620 using Microchip's MPLAB IDE and the HI-TECH PICC-18 PRO C Compiler package. The C driver code we will work through can be adapted to most any microcontroller with a USART or EUSART. I use the PIC18F2620 because it is a good middle-of-the-road PIC microcontroller that supports many of the standard PIC microcontroller features. Writing C for a "generic" PIC like the PIC18F2620 makes it a bit easier for you to port the code to another PIC microcontroller of your choice.

The LCD panel is supported by a PC application called MOGD#. MOGD# is a free Matrix Orbital support application that manages font and graphic downloads targeting the GLK240128-25 from the serial port of your PC. You can also use MOGD# to put the unit through its paces. I used MOGD# to preload the fonts I desired and to upload an optional graphic image.

I also found MOGD# useful when I was in the early stages of my learning curve. If something I wrote in C didn't work, I verified that the LCD panel could indeed perform my "failing" operation via MOGD#. Since we're primarily interested in displaying large amounts of text, let's begin our firmware assembly by writing some lines of C to support the text display commands.

All of these commands begin with the byte 0xFE. To move the cursor to the home position, we send the byte pair 0xFE 0x48. However, before we can send anything to the panel, we must initialize the PIC's EUSART:

```

//*****
//*          Initialize EUSART Function
//*****
void init_EUSART(void)
{
// load baud rate divisor for 19200 bps
// with 20MHz clock
SPBRG = 64;
TRISC7 = 1;           //receive pin
TRISC6 = 0;           //transmit pin
TXSTA = 0x04;         //high speed baud rate
RCSTA = 0x80;         //enable serial port

USART_RxTail = 0x00;   //flush rx buffer
USART_RxHead = 0x00;
USART_TxTail = 0x00;   //flush tx buffer
USART_TxHead = 0x00;

RCIP = 1;              //rx int = high pri
TXIP = 1;              //tx int = high pri
RCIE = 1;              //enable rx int
PEIE = 1;              //enable all ints
GIE = 1;
CREN = 1;              //enable USART1 rx
TXIE = 0;              //disable tx int
TXEN = 1;              //tx enabled
}

```

I've provided some important information in the EUSART initialization comments. For instance, our GLK240128-25 driver code timing is based on a 20 MHz clock. In that

19,200 bps is a standard baud rate, the SPBRG value of decimal 64 was pulled directly from the baud rate tables in the PIC datasheet. By the looks of the EUSART-related variables being initialized, the PIC18F2620's EUSART will be used in a buffered and interrupt-driven manner. Here are the EUSART buffer definitions:

```

//*****
//*          EUSART BUFFER DEFINITIONS
//*****
//1,2,4,8,16,32,64,128 or 256 bytes
#define USART_RX_BUFFER_SIZE 256
#define USART_RX_BUFFER_MASK ( USART_RX_BUFFER_SIZE - 1
)
// 1,2,4,8,16,32,64,128 or 256 bytes
#define USART_TX_BUFFER_SIZE 256
#define USART_TX_BUFFER_MASK ( USART_TX_BUFFER_SIZE - 1
)
unsigned char USART_RxBuf[USART_RX_BUFFER_SIZE];
unsigned char USART_TxBuf[USART_TX_BUFFER_SIZE];
unsigned char USART_TxHead,USART_TxTail;
unsigned char USART_RxHead,USART_RxTail;

```

The EUSART buffer mechanism is a classic head-tail circular buffer arrangement. Note that the transmit and receive buffer size values are all powers of 2. The reason for this lies in the way the buffer masks operate. The buffer masks are designed to wind through an entire transmit or receive buffer area in a circular manner as long as the buffer area is defined as a size that is a power of 2.

Once the EUSART is up and running, we can utilize the EUSART interrupts to send and receive characters. Right now, we're interested in getting two home-the-cursor bytes out to our GLK240128-25. The EUSART interrupt firmware I've written includes a function called sendchar, which transmits one byte at a time by way of the EUSART's transmit buffer (USART_TxBuf):

```

//*****
//*          SEND A CHARACTER
//*****
char sendchar(char usart_data)
{
char tmphead;
// calculate buffer index
tmphead = ( USART_TxHead + 1 ) &
           USART_TX_BUFFER_MASK;
// wait for free space in buffer
while ( tmphead == USART_TxTail );
// store usart_data in buffer
USART_TxBuf[tmphead] = usart_data;
// store new index
USART_TxHead = tmphead;
// enable TX interrupt
TXIE = 1;
return usart_data;
}

```

Here's how we employ the services of the sendchar function to home the cursor:

```

//*****
//*          HOME THE CURSOR
//*****
void home_cursor(void)
{
rc = sendchar(0xFE);
rc = sendchar(0x48);
}

```


The variable `rc` is short for return code. You can use the return code as a verification device as the return code in this case should be equal to the character that was sent. We can use the same `sendchar` function to arbitrarily set the cursor position. The syntax for cursor positioning is `0xFE 0x47 [column][row]`:

```
//*****
/** SET THE CURSOR POSITION
//*****
void position_cursor(char column,char row)
{
    rc = sendchar(0xFE);
    rc = sendchar(0x47);
    rc = sendchar(column);
    rc = sendchar(row);
}
```

When displaying text, positioning the cursor is an absolute necessity. Being able to clear the screen is also a very desirable function. I think you've already broken the code. So, if I give you the command syntax for clearing the LCD panel (`0xFE 0x58`), I believe your code would look like this:

```
//*****
/** CLEAR THE SCREEN
//*****
void clear_screen(void)
{
    rc = sendchar(0xFE);
    rc = sendchar(0x58);
}
```

Piece of cake. This is all fine until we get ready to push some text out to the display. What if we wanted to display the message "NUTS AND VOLTS" at the home position? You already know how to send the cursor home. So, here's the code to display our message:

```
//*****
/** DISPLAY SOME TEXT USING SENDCHAR
//*****
void display_text(void)
{
    rc = sendchar('N');
    rc = sendchar('U');
    rc = sendchar('T');
    rc = sendchar('S');
    rc = sendchar(' ');
    rc = sendchar('A');
    rc = sendchar('N');
    rc = sendchar('D');
    rc = sendchar(' ');
    rc = sendchar('V');
    rc = sendchar('O');
    rc = sendchar('L');
    rc = sendchar('T');
    rc = sendchar('S');
}
```

That's a lot of typing to only display 14 characters. Even if you cut and paste the `sendchar` statements, you would need a road map to navigate the longer messages in your source code.

The `sendchar` method works well with commands and short pieces of text. However, what if we needed to

display hundreds of characters? How would we handle displaying data that is constantly changing over time? Let's rewrite our NUTS AND VOLTS message code:

```
//*****
/** DISPLAY SOME TEXT USING PRINTF
//*****
void display_text(void)
{
    printf("%c%c%c%c NUTS AND VOLTS",
           0xFE,0x47,1,1);
}
```

Whoa! Only one line of code! There's even a position the cursor command mixed in with our text message. Each `%c` in the `printf` statement is respectively associated with the numeric values outside of the quotes. Those values located at the end of the `printf` statement constitute a position cursor command. The coordinates of the position cursor command are column 1, row 1. Thus, the text NUTS AND VOLTS will be displayed beginning at column 1, row 1.

The `printf` function does not utilize the interrupt-driven EUSART firmware. So, nothing gets buffered and no EUSART interrupts are triggered when the `printf` function is called. I think you already know how to rewrite all of the `sendchar` cursor movement functions using the `printf` method. So, we'll move on.

Suppose we want to monitor and display four tank temperatures driven by three independent systems. Just thinking about performing this task using the `sendchar` method gives me the willies. So, let's write the code using the easier and cleaner `printf` method. We'll start by rewriting our clear screen function:

```
//*****
/** CLEAR SCREEN
//*****
void cls_lcd(void)
{
    printf("%c%c",0xFE,0x58);
}
```

I don't think we need to expound on the obvious. With that, here's the display code:

```
//*****
/** DISPLAY TANK TEMPERATURES
//*****
void display_data(void)
{
    cls_lcd();
    printf("%c%c%c%c NUTS AND VOLTS / DESIGN
CYCLE",0xFE,0x47,3,1);
    printf("%c%c%c%c TANK1",0xFE,0x47,1,5);
    printf("%c%c%c%c TANK2",0xFE,0x47,1,6);
    printf("%c%c%c%c TANK3",0xFE,0x47,1,7);
    printf("%c%c%c%c TANK4",0xFE,0x47,1,8);
    printf("%c%c%c%c SYS_A",0xFE,0x47,7,3);
    printf("%c%c%c%c SYS_B",0xFE,0x47,14,3);
    printf("%c%c%c%c SYS_C",0xFE,0x47,21,3);

    tempF = (1.8 * 100) + 32;
    printf("%c%c%c%c %3.2f",
           0xFE,0x47,7,5,tempF);
    printf("%c%c%c%c %3.2f",
```

```

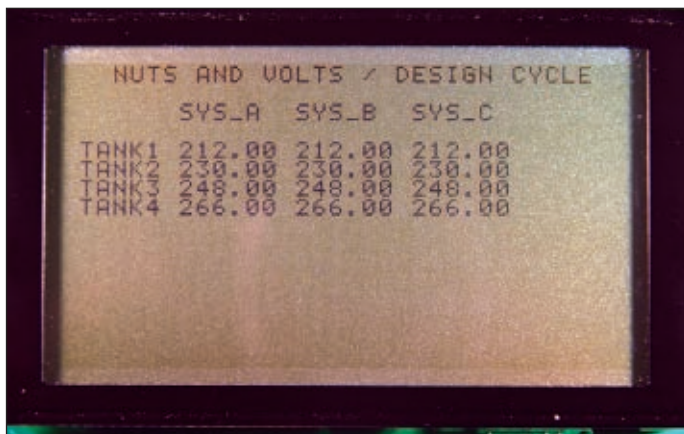
        0xFE, 0x47, 14, 5, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 21, 5, tempF);
mdelay1(100);
tempF = (1.8 * 110) + 32;
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 7, 6, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 14, 6, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 21, 6, tempF);
mdelay1(100);
tempF = (1.8 * 120) + 32;
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 7, 7, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 14, 7, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 21, 7, tempF);
mdelay1(100);
tempF = (1.8 * 130) + 32;
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 7, 8, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 14, 8, tempF);
printf("%c%c%c%c %3.2f",
        0xFE, 0x47, 21, 8, tempF);
mdelay1(100);
}

```

Every call to the printf function includes a cursor position command with the associated column and row coordinates. The tempF variable is defined as floating point. In our code, we have limited the temperature display to three significant digits supported by a resolution of 1/100th of a degree Fahrenheit behind the decimal point. I've taken the liberty to plug in some Celsius temperature values that get converted and displayed as Fahrenheit. Naturally, the raw temperature values would be streaming in from other functions operating within the microcontroller application.

The GLK240128-25 is capable of implementing flow control at its RS-232 interface. Instead of incurring the small amount of firmware overhead that comes with coding flow control routines, I've coded in adequate single-line millisecond delays (mdelay1(100);) that will allow the PIC and the panel to successfully complete the RS-232 transfers and display the resultant data. When the

■ **PHOTO 4.** We've displayed more information than a 4 x 40 character LCD can handle and, as you can see, we still have plenty of area to display additional data.



display_data function is invoked from within our monitoring application's main function, we get the results you see in Photo 4.

PROCESSING IMAGES AND KEYSTROKES

I created a very simple JPEG image using a web design program. I used MOGD# to upload the JPEG image into the unit's bitmap memory. Here is the code that forms a function that converts my little JPEG image into GLK240128-25 pixels:

```

//*****
//* DISPLAY STORED IMAGE
//*****
void display_image(char image_id)
{
    printf("%c%c", 0xFE, 0x58);
    printf("%c%c%c%c",
            0xFE, 0x62, image_id, 0x01, 0x01);
}

```

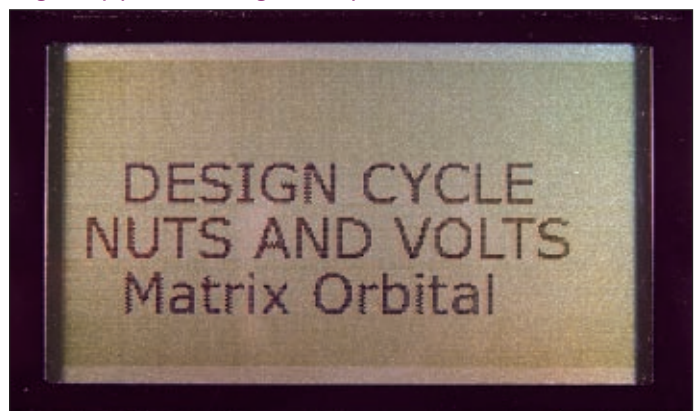
The display_image function clears the screen and proceeds to invoke the draw a bitmap from memory command. I hardcoded the image display bounds to begin drawing the bitmap image at X/Y coordinates 0x01 and 0x01, respectively. I used MOGD# to upload my JPEG image into image slot 1 of the unit's image memory. So, to get the JPEG to display on the LCD panel, I called the display_image function in this manner:

```
display_image(0x01);
```

I warned you earlier that I am not an artsy guy. That fact is pretty much proven in Photo 5, which happens to be a bitmap image of the JPEG I created.

Getting a character out in response to a keypress is just as easy as putting bitmap images up on the LCD panel. Let's say you want to implement a simple single-key reset key function using the keypad matrix. We don't want to send but one reset character per keypress. So, we must

■ **PHOTO 5.** This is a cool feature. Obviously, I'm art-challenged. However, the Matrix Orbital GLK240128-25 can render some amazing graphics for those of you that regularly perform magic with pixels.



put the keypad matrix system into Key Up/Down Mode. In this mode, the panel does not send characters continually while the key is depressed. Instead, it senses a key press and immediately sends the character associated with the key. No other characters will be transmitted until the key that is being depressed is released. Here's the command code to put in for Key Up/Down Mode:

```
printf("%c%c%c", 0xFE, 0x7E, 0x01);
```

LOST IN THE WOODS AT NIGHT IN THE RAIN

It's obvious that the GLK240128-25 is designed to be easy to deploy. I had absolutely no problems with the hardware or the MOGD# application. However, I did run into a gotcha with the RS-232 interface.

My initial PIC hardware design was driven by a 20 MHz ceramic oscillator. The PIC18F2620 showed no signs of any abnormality and its EUSART did not exhibit any problems when communicating with my TeraTerm Pro emulator. However, I could not communicate with the GLK240128-25 RS-232 port reliably at any of its supported baud rates. I figured I had a bogus unit. I happened to have two of them and swapping in a new unit didn't change a thing. So, I placed a call to Matrix Orbital's support center and began a problem-solving conversation with Troy Clark. Troy was very supportive and was always available to take my calls.

After several days of emails and phone calls to Troy, I narrowed the problem down to the ceramic oscillator that I was using to clock the PIC18F2620. There was absolutely no science or logic associated with finding the root cause of the problem. I stumbled into the fix. In complete desperation, I replaced the 20 MHz ceramic oscillator with a 20 MHz crystal and the panel never lost another

character when communicating with the PIC18F2620. I won't disparage the ceramic oscillator manufacturer here as my problem may be an isolated incident. Needless to say, I trashed my stock of that manufacturer's ceramic oscillator devices.

WRAP-UP

You have been exposed to a pair of methods (sendchar and printf) that allow you to exploit the full feature set of the Matrix Orbital GLK240128-25. The sendchar method is more suited for smaller applications that are being driven by PIC microcontrollers with limited memory resources. PIC microcontrollers with larger program memory areas can take advantage of the printf command method.

We've only scratched the surface of this panel's capabilities. Reading about what it can do does not do this LCD panel justice. I've given you a firmware jump start on putting one to work. To get a feel for how versatile the GLK240128-25 really is, you'll just have to get a one of your own and meld it into your Design Cycle. **NV**

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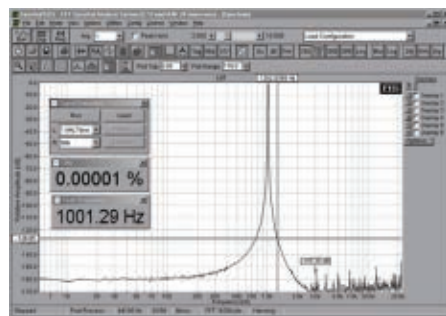
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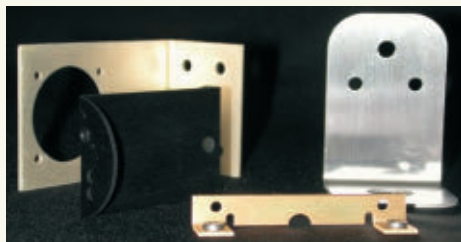
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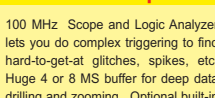
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■ BY L. PAUL VERHAGE

NEAR SPACECRAFT RECOVERY SYSTEMS: PART 2

LAST TIME, we sewed a parachute canopy, so this month we'll add the shroud lines and spreader ring to complete it. Then, we'll wrap up with an electronic recovery device that you may want to add to your parachute. Are you ready?

SHROUD LINES

To make parachute shroud lines, you'll need string, a black felt tip marker, large bearing swivels (larger than #3), split rings (one inch diameter), and heat shrink tubing (3/8 inch diameter ought to be fine). The best string for shroud lines is a woven cord; don't use twisted nylon cord, as it will fray over time. I strongly recommend Spectra, a kite string available from stores like Into The Wind (www.intothewind.com). You must melt the cut ends of Spectra or it begins to fray. So after cutting the Spectra, hold the end of the string

above the flame of a match or lighter. Don't burn or ignite the cord, just heat it enough that it begins to melt and ball up. For a 12 pound near spacecraft, 120 or 150 pound test Spectra is fine for the shroud lines.

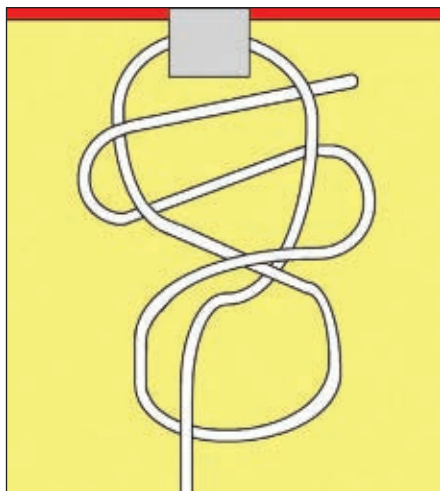
I read many years ago that shroud lines should be twice as long as the diameter of the parachute. This advice has worked well in the nearly half dozen parachutes I've made to date. Therefore, since there are eight attachment points on the parachute canopy and one shroud line connects to two of the points, we need to cut four lines; each 24 feet long of kite line. Mark the kite line 24 feet from the end with the felt tipped marker and cut the line just past the mark. Then, carefully heat the cut end until the line melts to the mark. Now repeat this three more times.

Before tying the shroud lines to the canopy, find and mark the middle of each one. Then, mark spots one inch before and after the center mark. Slide a bearing swivel over the center mark and tie an overhand knot in the kite line, trapping the swivel in the knotted loop between the one inch marks. Use just a bearing swivel; don't use a snap swivel because I can tell you from first-hand experience that the snap swivel will open up at the wrong time during a near space mission. Since knots weaken lines, I like to slide a piece of heat shrink tubing over the knot and

shrink it down. After tying the bearing swivels to the center of the four shroud lines, it's time to attach the ends of the shroud lines to the parachute canopy. The knot used to attach the shroud line to the parachute must resist pulling loose. Better yet, the knot should get tighter if pulled. I've used a couple of knot types in the past and find the half blood knot works well. I've diagrammed the knot below and hope you'll find it helpful in tying this knot.

Measure and mark a point six inches from the end of the shroud line. Then, pass the end of the shroud line through one of the twill tape loops at the end of the canopy and center the mark inside the loop. Now tie the knot. In some parachutes, I've covered these knots in heat shrink. If you want to do the same, then you must slide heat shrink over the end of the shroud line before tying it to the parachute canopy.

After attaching the shroud lines, I can't help but take the parachute outside and run with it. It's satisfying to watch the parachute pop open and give a large tug. The parachute is ready to fly at this point; however, if you attach the parachute in its present state, the top module will



A half blood knot, as best as I can draw it. There are webpages of knots out there, if you need a better explanation. Kite books are also a good source of knotty information.

NOTE: All PCB patterns and files are available on the *Nuts & Volts* website at www.nutsvolts.com.

take some sideways force when the parachute snaps open and fluctuates in size. These forces of compression can be dampened with a spreader ring.

THE SPREADER RING

The spreader ring is just an inexpensive cross stitch or embroidery hoop. I prefer the older wooden ones as I don't believe the plastic ones are strong enough to stand up to the cold and stress of a near space mission. An alternative material that other near space groups have used is a small, round cooling rack. I've never experimented with attaching shroud lines to something like this, so let me explain how I convert a cross stitch hoop into a parachute spreader ring.

First, you'll notice that a cross stitch hoop consists of two pieces: an inner ring of fixed diameter and an outer loop of variable diameter. To make the hoop stronger, epoxy the inner ring to the outer ring and lock them together tightly with the outer hoop's clamp. After the epoxy sets, file off the metal clamp from the outer hoop and fill the gap in the ring with a bit of bass wood and epoxy.

Now locate and mark the quadrants of the hoop. I do this by drawing a right angle cross on a sheet of paper and centering the hoop over the diagram. Drill a small hole (1/8 inch works well) through the cross stitch hoop, centered at each quadrant.

Now cut a piece of kite line three feet long and melt its ends. Divide and mark the cord into thirds. Slide two bearing swivels on the line and tie them at the one-third and two-third marks. Then, pass both free ends of the cord through one hole in the cross stitch hoop and tie them into a knot on the other side. The ends of the cord fit snugly through the hole and it's difficult or impossible to pull the knot through. For added girth to the knot, add some heat shrink over it. Now repeat this process for the other three holes in the spreader ring. The quickest way to connect the spreader ring to the

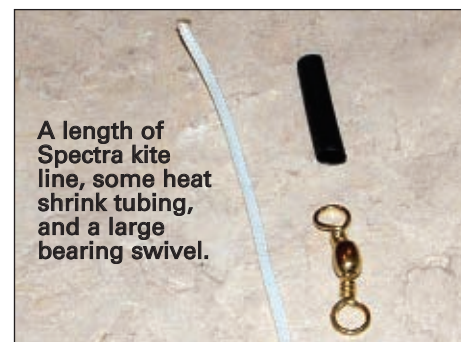
top module and parachute's shroud lines is with a split metal ring (the kind used for keys). Don't use hinged locking rings because they'll pop open during a mission. A bearing swivel cannot pop out of a split metal ring, so the split ring is more secure. Only under extreme conditions will a split ring untwist and opened up. I've used one inch split rings on my parachutes and have not experienced a failure in over 65 missions. By the way, split rings are available in many arts and crafts stores.

THE PARACHUTE APEX

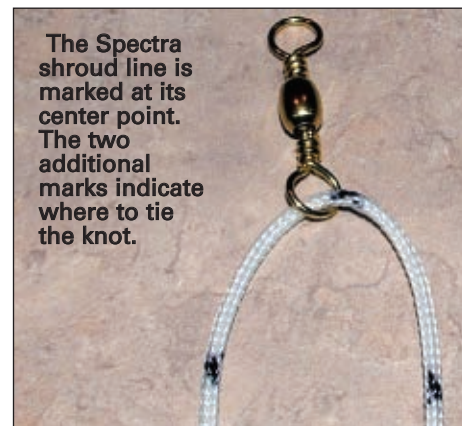
The parachute apex attaches to the balloon with a load line and bearing swivel. With a bearing swivel at the top of the canopy, less of the balloon's rotation transfers to the near spacecraft below. Make an apex cord from one or two feet of kite line and melt its ends. Then, find and mark the center of the kite line and pass it through one loop of a bearing swivel. Tie an overhand knot in the line, attaching the bearing to the kite line at the center mark. Now locate and mark the center of the four twill tapes crossing over the spill hole of the canopy. Wrap the other end of the kite line around the center of the twill tapes and tie a second overhand knot in the kite line.

At the launch site, tie the load line from the balloon's neck to the top loop of the bearing swivel and then cover the knot in some duct tape. Be sure that only the metal loop is taped over and not the rotating bearing. And even if Boy Scouts tie the knot, wrap the knot in duct tape for additional security.

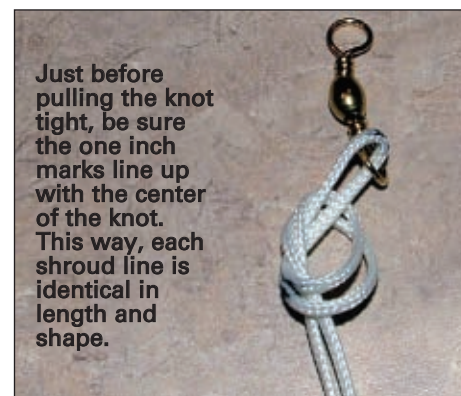
There's nothing more aggravating than untangling shroud lines at the balloon launch site. Thanks to Mike Manes of the Edge of Space Sciences group in Colorado. I've learned the best way to avoid this problem. After getting the parachute shroud lines untangled the night before a launch, wrap a few wire twist ties around the shroud lines. Now the shroud lines can't move around and tangle up before launch. Just be sure you remove the twist ties before launch-



A length of Spectra kite line, some heat shrink tubing, and a large bearing swivel.



The Spectra shroud line is marked at its center point. The two additional marks indicate where to tie the knot.



Just before pulling the knot tight, be sure the one inch marks line up with the center of the knot. This way, each shroud line is identical in length and shape.



I wasn't too happy with my first attempt to position the heat shrink on this shroud line, so I used a second piece of heat shrink to partly cover the first. Cut your heat shrink long enough so you won't have this problem. Also, warm the heat shrink tubing as gently as possible so the Spectra doesn't begin to melt.



Connecting bearing swivels is fast and easy with split rings like these.



The parachute apex with its bearing swivel.

ing the balloon or you'll get a very fast descent after the balloon bursts.

AN ELECTRONIC RECOVERY AID

Now let's look at an electronic device that you might add to your parachute as an aid to recovery. Normally, a burst balloon remains attached to the apex of the parachute during the descent to the ground. This doesn't harm the descent, but does make it more chaotic due in part to the weight and drag of the burst balloon trailing behind the parachute at the end of a 20 foot load line. As the burst balloon swings around, it tugs on the parachute causing it to swing and tip. If we cut away the balloon, there'll be no off-balanced forces pulling on the parachute and the descent is more like an elevator ride.

Many near spacecraft carry an audio beacon to help locate it when

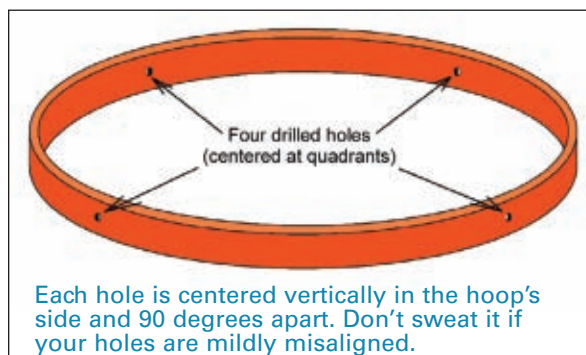
it lands in tall grass or a corn field. The downside of the audio beacon is that it starts wailing away while you're launching the near spacecraft. It's not pleasant to be the one nearest the audio beacon during a near spacecraft launch. (Man, it sure would be nice if the audio beacon would only start up on descent or later.)

THE SMART CUTDOWN

The recovery aid I designed to counter the two problems mentioned above is the Smart Cutdown. It's PICAXE controlled and can cut away the balloon and start the audio beacon based on either mission elapsed time (MET) or a

radio signal (or lack thereof) from the near spacecraft. This device cuts away the balloon by melting the load line running through its nichrome coil. An I/O pin of the PICAXE operates the coil by controlling a simple SPST reed relay. The coil only needs to get hot for a few seconds to melt the load line. After melting, the balloon is free to continue ascending if it hasn't burst yet. This gives the Smart Cutdown the ability to terminate the ascent of a near space mission at any point. If the balloon has already burst, then the balloon and load line drop away from the parachute, making the descent easier on the near spacecraft.

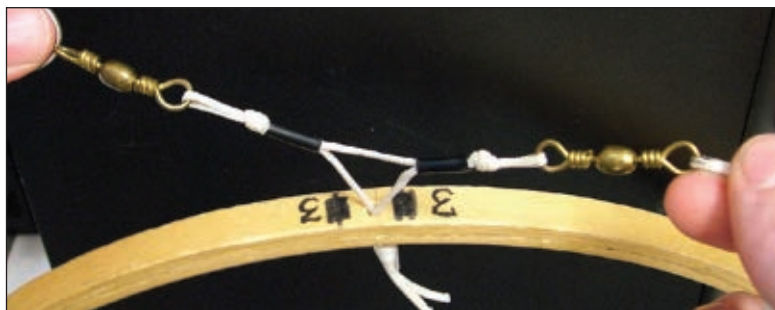
To enable the nichrome coil to melt the load line in just a few seconds, the coil needs insulation from the cold near space air. Not



Each hole is centered vertically in the hoop's side and 90 degrees apart. Don't sweat it if your holes are mildly misaligned.



The outer hoop's clamp was removed and the gap was filled with a block of basswood. The letter visible on the hoop's side was part of a test. I was experiencing too many knots in the shroud line and thought labeling every connection would help reduce their numbers.



Two bearing swivels attached to the cross stitch loop. I don't feel the heat shrink next to the bearing swivel knots is necessary anymore.



To make the interior knot larger and more resistant to coming unknotted, there's a sleeve of heat shrink over it.

only must the coil be protected from the air, but the parachute and possibly the ground must be protected from the hot coil should the balloon have already burst or the near spacecraft has already landed when the relay fires. To retain heat and protect the parachute and ground, mount the Smart Cutdown inside a Styrofoam box.

The SCR on the circuit switches on the audio beacon. However, I discovered several years ago that the audio beacon doesn't always draw power. As a result, the audio beacon forces the SCR to shut down after one beep. To get around this, the Smart Cutdown adds an LED circuit in parallel to the audio beacon. So even when the audio beacon temporarily stops drawing current, the LED keeps the SCR "on" by drawing a small constant amount of current. In this way, the SCR acts as a latching relay that keeps the audio beacon functioning when the PICAXE stops putting voltage on the SCR's gate.

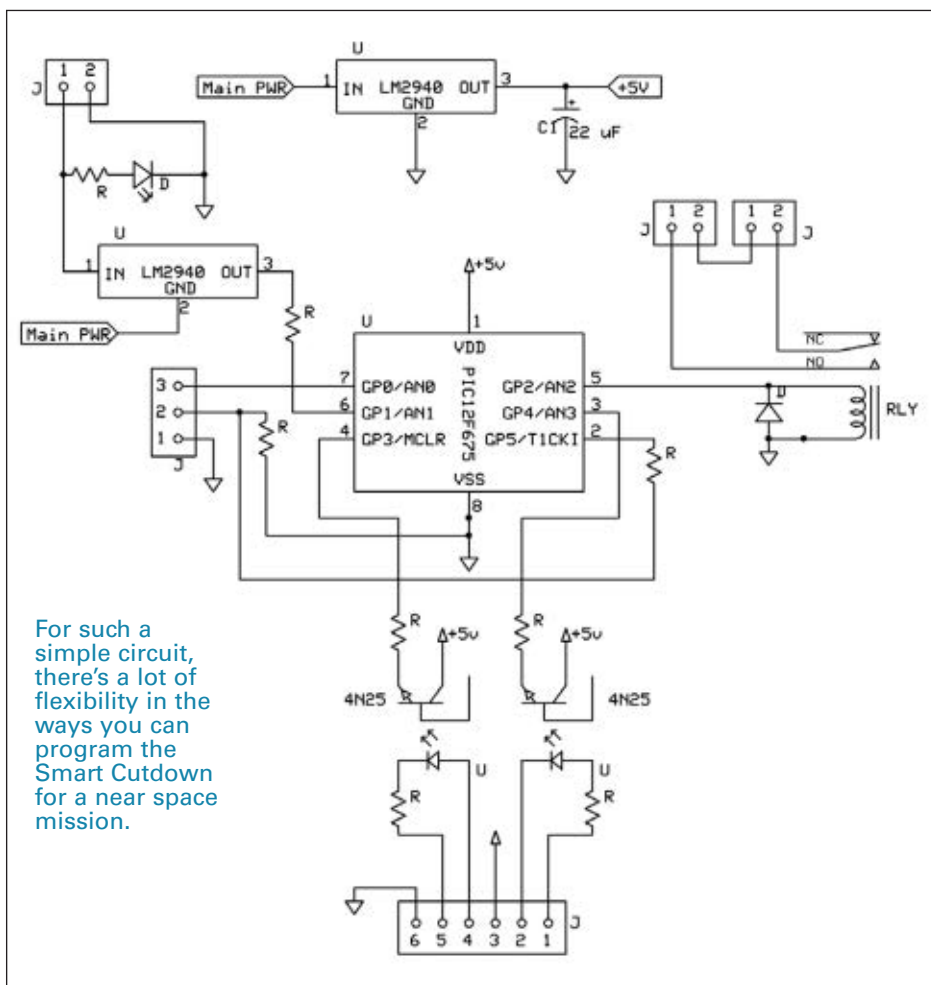
The program in the Smart Cutdown should cut the balloon away between 90 and 120 minutes into the mission, which is long enough for the balloon to finish a normal ascent. However, the PICAXE is smarter than just that. With the attached toy radio receiver, the PICAXE can respond to commands from the near spacecraft. The GPS inside the near spacecraft, an accelerometer, and a thermometer each can signal the near spacecraft's flight computer that the balloon has burst, that the mission has reached the maximum desired altitude, or that the desired mission elapsed time has arrived. The near spacecraft can then use a toy transmitter to signal the Smart Cutdown to terminate the flight. However, this is not all. Since the Smart Cutdown's toy radio has two channels, one channel can confirm the cutdown command from the first channel or even act as an electronic heartbeat for the near spacecraft's flight computer. As a heartbeat, the flight computer transmits a regular pulse, say two seconds long every minute, signaling

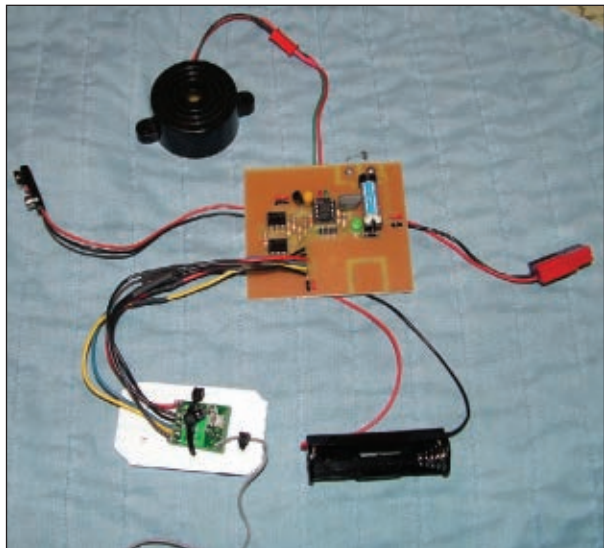
LISTING 1

```
* ****  
* Pinout Notes *  
* output 1 = beacon (SCR + LED) *  
* output 2 = cutdown (relay) *  
* input 3 = RC channel *  
* input 4 = RC channel (not working in this test) *  
*****  
  
SmartCutDown:  
    IF INPUT3 = 0 THEN SmartCutDown      `wait for the signal  
  
Verify:  
    PAUSE 1010  
    IF INPUT3 = 1 THEN SmartCutDown       `verify it went low in 1s  
    PAUSE 1010  
    IF INPUT3 = 0 THEN SmartCutdown       `verify it went high in 1s  
  
Verified:  
    HIGH 2                               `activate line cutter  
    PAUSE 3000                           `wait 3 sec to cut line  
    LOW 2                                `deactivate line cutter  
    HIGH 1                               `start beacon  
    PAUSE 500  
    LOW 1  
  
END
```

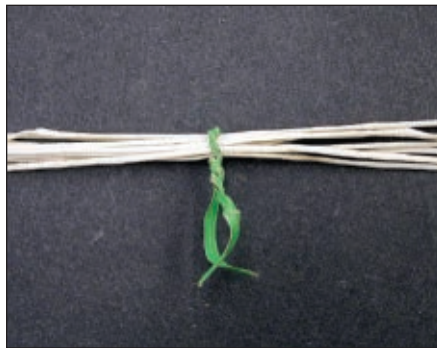
the Smart Cutdown that all was well with the near spacecraft. When the pulses stop (flat lines), the Smart Cutdown assumes the flight computer has died and takes over by terminating the flight. The sooner a failed near space mission is terminat-

ed, the lower its altitude and the sooner in time and space it will land, improving its odds of a successful recovery. Toy R/C communication like this enables very powerful features, and best of all, since the radio has such short range, there's





The Smart Cutdown. Attached to the top of the PCB is the loud and annoying audio beacon. Also visible at the top is the coil of nichrome wire that will melt the load line connecting the parachute to the balloon.



It only takes three of four equally spaced twist ties to prevent the shroud lines from tangling. They're also very easy to remove at the launch site— a factor that's very handy on cold mornings.

virtually no way for spurious transmissions to trigger a false signal.

BUILDING THE SMART CUTDOWN

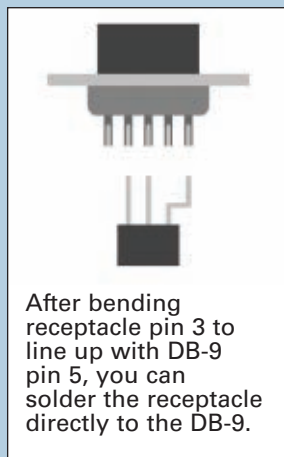
There are no gotchas on this PCB, but do be careful when you solder the radio receiver to the board. The miniature radio receiver is part of an inexpensive, two channel radio controlled car modified as I

described in the June '04 issue of *SERVO Magazine*. Removing the tiny PCB and soldering new wires to it can be stressful on the board if

PICAXE Programmer

After arriving in Kansas this summer with my new wife, I discovered that I had misplaced my PICAXE programmer. Rather than spending an inordinate amount of time looking for it in all the moving boxes, I made a new one with the items I had on hand: hot glue, a female DB-9 connector, its plastic housing, and a spare two-row receptacle. The receptacle I used is a high quality 2 x 32 glass-filled epoxy body with 0.5 inch gold plated leads. I brought a lot of these 2 x 32 receptacles with me to Kansas and if you'd like one, contact me through Email. Since the receptacles can't be snapped to length, I pulled the fourth column of pins and sawed through the now opened receptacle with an X-acto saw. I then finished modifying the receptacle by sanding the cut end with a small metal file to make a smooth edge.

During programming, a PICAXE connects to pins 2, 3, and 5 of a DB-9 connector. The order and spacing of the pins in the common three pin header used to program a



After bending receptacle pin 3 to line up with DB-9 pin 5, you can solder the receptacle directly to the DB-9.

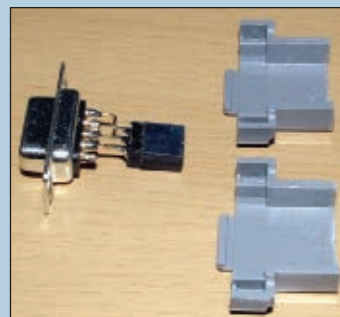


The PICAXE programmer after soldering the receptacle to a DB-9 connector.

PICAXE in-circuit matches the order and spacing of the DB-9 connector, if pin 3 of the header is bent in line with DB-9 pin 5.

I did a small cheat when I soldered the header to the receptacle. After soldering a row of pins into the DB-9, I shortened the second row of three pins and soldered them to the longer first row. This way, either row of the 2 x 3 header can program the PICAXE. The soldered connection between the receptacle and DB-9 is strong enough to use as a programmer as-is. However, for long term durability and protection from shorts, I made a proper housing for the programmer by sawing a plastic DB-9 housing in two just before the bolt holes as you can see in the photo.

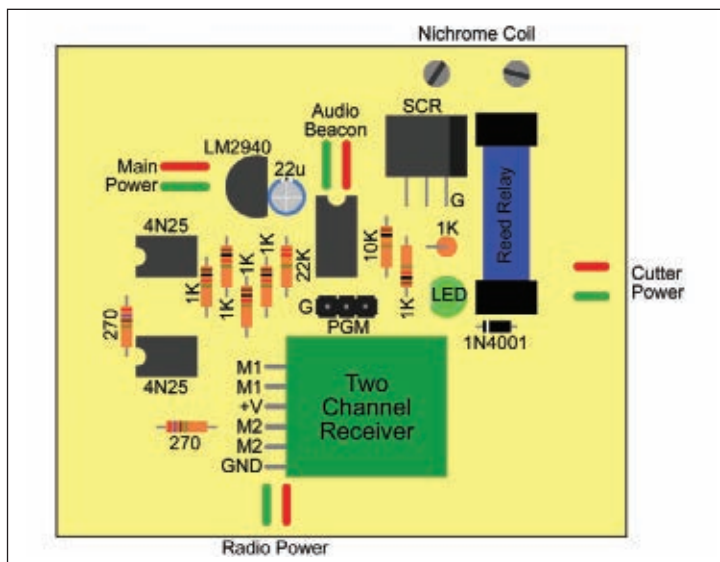
Next, I filled the receptacle halves with hot glue and closed them with the programmer inside, then back-filled the open space around the receptacle so it became a solid block of plastic. For good measure, I shrank a band of heat shrink around the back end of the closed housing and marked the ground pin with a drop of green paint.



The case is cut short enough that the receptacle will protrude a small amount beyond the end of the case.



The completed programmer. Be sure to observe which side of the receptacle has the green dot when plugging it into the PICAXE circuit.



The placement of parts for the Smart Cutdown.

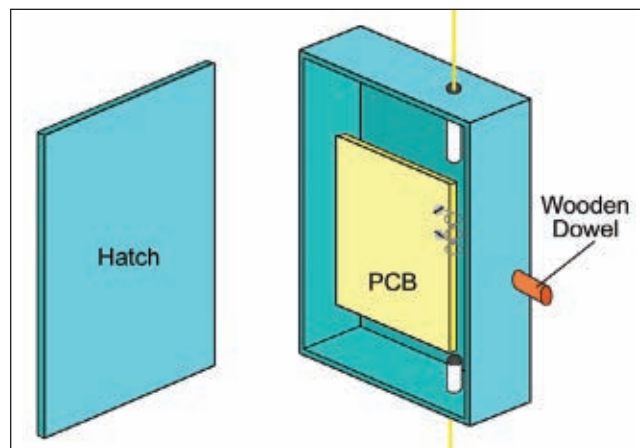
you're not careful. In fact, the radio I used to test the Smart Cutdown had one failed channel and I'm not certain how or when I damaged it. So exercise some care. The Smart Cutdown PCB is designed for the miniature radio receiver to be mounted to it, but I connected my radio through a six wire harness in case the radio needed isolation for the PCB. The motor outputs from the miniature radio receiver connect to the inputs of the two optoisolators (the 4N25s) on the PCB. If the near spacecraft operates the desired button on its toy transmitter, it energizes an LED inside the Smart Cutdown's opto. The LED's light causes the NPN transistor inside the 4N25 to conduct, letting current flow to the PICAXE for detection.

The four wire pairs (main power, radio power, cutter power, and audio beacon) connected to the Smart Cutdown PCB are strained relieved by passing them through holes drilled in the PCB. The cables then exit the PCB from beneath it.

The miniature radio receiver's voltage depends on the toy R/C car you purchase. In the Smart Cutdown pictured in this article, the radio uses a single 1.5 volt AA cell. Main power can be a six volt lithium battery as can the cutter power. However, test the cutter power on the ground before a mission. Some lithium cells will not source enough current to melt a load line running through the nichrome coil as a safety feature. This can occur with rechargeable cell phone batteries, but I was able to use a non-rechargeable lithium camera battery in a prior test.

Speaking of the cutter, the hot wire cutter is three inches of 30 gauge nichrome wire. It's wrapped around a 1/8 inch dowel for shaping and then bolted to the PCB with 2-56 hardware. Below is the PICAXE code I used to test the completed Smart Cutdown. In it, a BASIC Stamp signaled the cutdown with two on-off pulses of one second each. In a real mission, the flight computer would signal with one radio channel and then verify with the second (say by alternating pulses).

Well, it looks like we're running out of space in this



Since the Smart Cutdown enclosure is not subject to much force, a thin walled Styrofoam box provides all the necessary protection for the nichrome coil. The enclosure hooks to the parachute's apex, leaving the load line free to slide through the nichrome coil. Do not tie the load line to the enclosure or Smart Cutdown.

month's issue. Next time, I'll include a sidebar on reefing parachutes with a second electronic recovery aid. If you'd like to receive a copy of a Smart Cutdown PCB, contact me. I'd be happy to make one at nominal cost. You can reach me at my new email address at NearSys@gmail.com

Onwards and Upwards,
Your near space guide **NV**

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GETTING STARTED WITH PICs

THE LATEST IN PROGRAMMING MICROCONTROLLERS

■ BY CHUCK HELLEBUYCK

GETTING STARTED ON YOUR HOLIDAY GIFT LIST

With the holidays looming, I wanted to pass along a holiday shopping list that you can pass on to your loved ones who don't have a clue what to get for you.

I'm sure buying for the readers of this column isn't easy for their family members, since even a hint for a PICkit™ 2 development board won't make a lot of sense if the relative isn't into electronics. So, here is my recommended list of products for the "Getting Started with PIC MCUs" crowd.

PICKIT™ 2 STARTER KIT

If you've been reading this column on a regular basis, you know that I think the PICkit 2 Starter Kit (see Figure 1) is the best starter package for the beginner. It gives you all the pieces you need to get started programming, including a PIC16F690 MCU. The package includes a CD that has a sample version of the HI-TECH PICC-Lite™ C compiler and a sample version of microEngineering Labs' PICBASIC PRO compiler. You also get sample code for the Microchip MPASM™ assembler if you want to learn assembly code. For \$49.95, this is a

■ FIGURE 1. PICkit™ 2 Starter Kit.



great holiday gift. You can buy these from various sources, including Mouser (www.mouser.com), Jameco (www.jameco.com), and microchipDIRECT (www.microchipdirect.com).

You may already have the PICkit 2 Starter Kit but want another one for your lab to use the UART or Logic Analyzer tools built into the PICkit 2 software. I have five PICkit 2 Starter Kits in my lab so I'm a little out of the ordinary, but having a second one is highly recommended. You can purchase just the programmer without the development board. The interesting thing is that the CD is identical to the starter kit CD, so you get all the free stuff without the extra cost. Add your own choice of development board and you can make a custom PICkit 2 Starter Kit.

PICKIT™ 2 DEVELOPMENT BOARDS

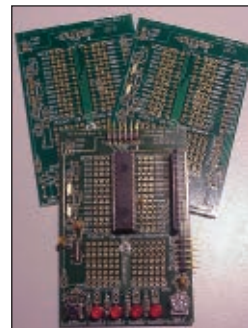
You have numerous development boards to choose from for the PICkit 2 Debugger/Programmer. You can get them in a 20-pin version with a PIC16F690 MCU that also supports the eight and 14-pin parts. You can get an 18-pin version with a PIC16F648 MCU and a 28-pin version with a PIC16F886 MCU onboard. These all come in packs of three with one board fully populated with the PIC MCU in a DIP socket,

and then two blank boards.

There is also a 40-pin board that is used in the PICkit 2 Debug Express package — a PIC16F887 in a surface-mount package part that is soldered to the board. You can get one fully populated version and two blank boards. If you don't want to work with surface-mount parts, this may not be your best choice. However, you can create a PICkit 2 Debug Express by adding this to your PICkit 2 programmer.

Finally, there is a PIC18F87J10 development board that has an 80-pin part soldered to it. That is a lot of I/O for such a small board. If you need the I/O and increased memory, then this may be worth a look.

■ FIGURE 2. 28-pin Development Boards.



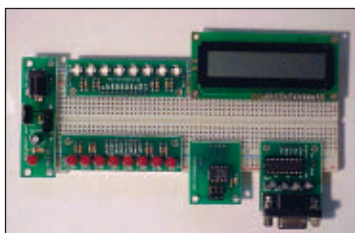
■ FIGURE 3. PIC18F4XK20 Starter Kit.



PIC18F4XK20 STARTER KIT

Additionally, there is a PIC18F4XK20 development board (see Figure 3) that is part of a starter kit which includes a PICkit 2 programmer. This development board has a lot of nice features, including an OLED display. If you want to get started with the PIC18F MCU and the Microchip MPLAB PIC18 C compiler, this is a great package.

BREADBOARD MODULES



■ FIGURE 4. Breadboard Modules.

Now, if you like to develop with breadboards — like I often do — then you may like to add the breadboard modules (see Figure 4) from Beginner Electronics (www.beginnerelectronics.com) to your list. These boards are designed to plug in to both the power rails (for powering the module) and the breadboard's general-purpose area (for connecting to a MCU). There are various versions available for the different projects you might create.

There are voltage-regulator, momentary-switch, LED, EEPROM, RS-232, and relay module versions, as well as one with an LCD. All are designed to plug into a breadboard. Since the modules don't fit every type of breadboard so Beginner Electronics also sells the breadboard and wire kit.

PICBASIC™ PRO FULL COMPILER



Now is the time to ask for the full version of the PICBASIC PRO compiler

■ FIGURE 5. PICBASIC™ PRO Compiler.

(see Figure 5). I often use the sample version in the articles here, but once you get the full version, you'll wonder how you survived without it. You will be able to write programs as big as you want, using any of the PIC12F, PIC16F, and PIC18F MCUs. If you need a book to help you get started using this compiler, there are several available. (My first book, *Programming PIC Microcontrollers with PICBASIC* is one option). Some readers still email me about this compiler being too expensive. However, people who have bought and used it tell me they've gotten their money's worth.

PICBASIC STANDARD COMPILER



■ FIGURE 6. PICBASIC™ Standard Compiler.

The PIC BASIC standard compiler (see Figure 6) is a less expensive alternative to the

PRO version. It limits you to 2K word program space and doesn't have all the advanced commands that PIC BASIC PRO offers, but I mention it here because the command set is directly compatible with the PICAXE® chips. If you have a design based upon Revolution Education, Inc.'s, PICAXE and want more code space in a small, eight-pin part, then this compiler may be a great option as a next step. There are some PICAXE commands this compiler doesn't support, so check out the command set thoroughly before adding it to your list.

PIC® MCUs

You can never go wrong adding more PIC MCUs to your lab. Get a few free samples from <http://sample.microchip.com> for stocking stuffers. These are the parts I recommend you stock at a minimum. (You can also buy larger quantities of these from Mouser, Jameco and microchipDIRECT).

8-pin: PIC12F683

14-pin: PIC16F688
18-pin: PIC16F88
20-pin: PIC16F690
28-pin: PIC16F886
40-pin: PIC16F887
28-pin: PIC18F2520
40-pin: PIC18F4520

NUTS & VOLTS AND SERVO MAGAZINE

Back issues of *Nuts & Volts* or *SERVO Magazine* can never be a bad present. You can get them on CD and ordering information can be found in the pages of this magazine you are reading. Subscription renewals are a good idea, too.

BOOKS

I might as well get my self promotion out of the way and introduce my latest book, *Getting Started with PICs — 2006* (see Figure 7).

The book is a collection of the first 12 articles (January — December 2006) from this column, consolidated into a book. Having everything in a single bound book can be helpful. If you missed the early columns, this may be a nice gift for your list. This book retails for \$29.95 and can be purchased at my website (www.elproducts.com) and the *Nuts & Volts* online bookstore (www.store.nutsvolts.com).

The table of contents includes:

- January 2006 — Designing with the Microchip PIC
- February 2006 — Microchip PIC-Based Resistor Checker
- March 2006 — PIC-to-PC Communication
- April 2006 — Going Beyond 31 Commands
- May 2006 — Using the Microchip PIC Timers
- June 2006 — Using the PIC External Interrupt



■ FIGURE 7. My *Getting Started with PICs* book.

- July 2006 — Developing with a PIC Bootloader
- August 2006 — Multiplexed LED Displays and Relay
- September 2006 — Real-Time Clock
- October 2006 — USB PIC Programmers
- November 2006 — PIC Hardware Interface
- December 2006 — Christmas Music

Most of the articles in this book use

the PICBASIC PRO Compiler sample version.

Another book I recently released is *Beginner's Guide to Embedded C Programming*. It has been out a few months now and the



■ **FIGURE 8.** My *Beginner's Guide to Embedded C Programming* book.

feedback has been great. The book has eight projects that use the PICkit 2 Starter Kit. The book (see Figure 8) covers the basics of embedded C programming from the beginner's perspective, the same way I try to cover the BASIC language in *Nuts & Volts*. Some of the topics covered are:

- C language structure
- C language statements
- Functions
- Linking multiple C files
- How to control outputs
- How to read inputs
- How to read an analog voltage with an Analog-to-Digital Converter (ADC)
- MPLAB® Integrated Development Environment setup and operation
- PIC16F690 microcontroller register and configuration setup

This book retails for \$39.95. You can also find it at my website www.elproducts.com and the *Nuts & Volts* online bookstore.

CONCLUSION

I'm sure you have a holiday gift list of your own, but hopefully I gave you (or your family) some ideas for the "electronics hobbyist that's hard to buy for." Be sure and watch the Microchip website as it gets closer to the end of the year. In the past, Microchip has had a holiday development tool sale (usually in December) that allows you to buy some of this stuff at a discount. I don't know what percentage the discount will be or the exact date, but I have been told it will happen again this year. This may make it an even better holiday season for the *Nuts & Volts* reader!

Send me your comments and suggestions to chuck@elproducts.com. I'm going to take you a little deeper into the PIC MCU peripherals in my 2009 columns. Thanks for another great year, and for supporting my column. I look forward to continuing it in the new year. **NV**

NOTE: The Microchip name and logo, MPLAB, and PIC are registered trademarks of Microchip Technology, Inc., in the USA and other countries. MPASM and PICkit are trademarks of Microchip Technology, Inc., in the USA and other countries. All other trademarks mentioned herein are property of their respective companies.



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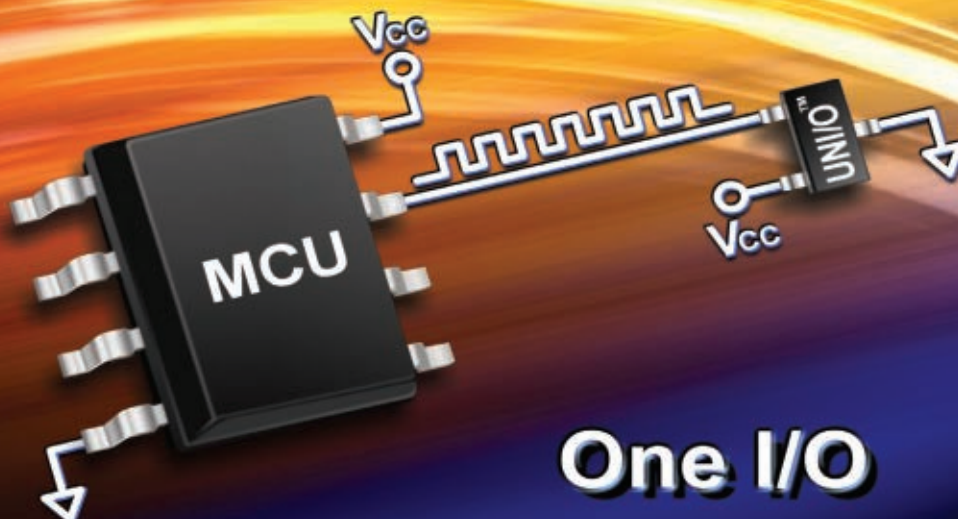
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11LC010	1K	2.5-5.5V
11AA020	2K	1.8-5.5V
11LC020	2K	2.5-5.5V
11AA040	4K	1.8-5.5V
11LC040	4K	2.5-5.5V
11AA080	8K	1.8-5.5V
11LC080	8K	2.5-5.5V
11AA160	16K	1.8-5.5V
11LC160	16K	2.5-5.5V

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Purchase the **MPLAB® Starter Kit for Serial Memory Products** (DV243003), which supports the UNI/O family of serial EEPROM and all other Microchip serial EEPROMs for \$79.98 at www.microchipDIRECT.com.



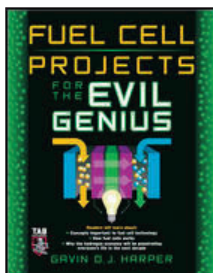
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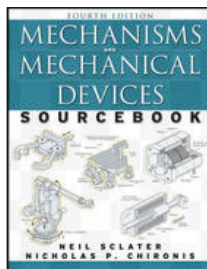
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ELECTRONICS

Beginner's Guide to Embedded C Programming Combo by Chuck Hellebuyck

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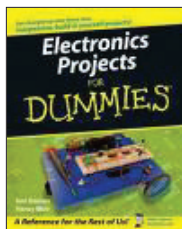


Book and Kit can be purchased separately.

The C language has been covered in many books but none as dedicated to the embedded microcontroller beginner. Through his down-to-earth style of writing, Chuck Hellebuyck delivers a step-by-step introduction to learning how to program microcontrollers with the C language. The PICkit 2 Starter Package is used for all the projects in the book and includes the HI-TECH PICC-Lite Compiler and a PIC16F690.

Reg \$89.95 Sale \$85.55

Electronics Projects For Dummies by Earl Boysen & Nancy C. Muir



Who says the Science Fair has to end? If you love building gadgets, this book belongs on your radar. Here are complete directions for building 10 cool creations that involve light, sound, or vibrations — a weird microphone, remote control gizmos, talking toys, and more, with full parts and tools lists, safety guidelines, and wiring schematics.

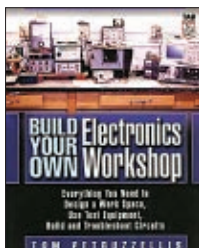
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By Thomas Petruzzellis

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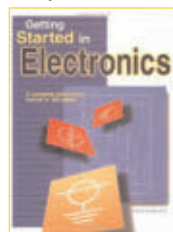
This value-packed resource provides everything needed to put together a fully functioning home electronics workshop! From finding space to stocking it with components to putting the shop into action — building, testing, and troubleshooting systems — popular electronics author Tom Petruzzellis' *Build Your Own Electronics Workshop* has it all! And the best part is, this book will save you money, big time! Reg **\$29.95 Sale Price \$24.95**



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by Forrest M. Mims III

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NEW!

Getting Started with PICs A Collection of 2006 *Nuts & Volts* Magazine Articles By Chuck Hellebuyck

In the January 2006 *Nuts & Volts Magazine*, Chuck Hellebuyck started a column titled "Getting Started with PICs" that

focused on the beginner. It became a popular column and continues in *Nuts & Volts Magazine* today. Many readers missed the early columns so this book contains the original 2006 articles compiled into a book for easy reference.

\$29.95



Fashioning Technology by Syuzi Pakhchyan

Ready to take your craft projects to the next level? This introductory DIY book demonstrates how to blend traditional sewing and

assembly techniques with new materials and electronics to create accessories, housewares, and toys that light up, make sounds, or do even more. In *Fashioning Technology*, you'll find: * An invaluable reference section that breaks down the materials, components, and tools with clear, concise explanations and photos; * A wide range of projects, including electronic accessories, interactive plush toys, and color-changing blinds, all using diverse crafting techniques.

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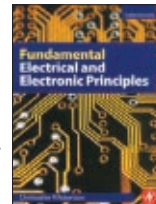


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by C R Robertson

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C Programming for Microcontrollers
by Joe Pardue

Book **\$44.95** Kit **\$66.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

The Virtual Serial Port Parts Kit and CD

(also available, above right)

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Do you want a low cost way to learn C programming for microcontrollers? This 300 page book and software CD show you how to use ATME's AVR Butterfly board (available in the kit, above right) and the FREE WinAVR C compiler to make a very inexpensive system for using C to develop microcontroller projects.

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PIC Microcontroller Project Book

by John Iovine

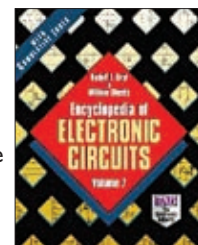
The PIC microcontroller is enormously popular both in the US and abroad. The electronics hobbyist market has become more sophisticated. This new edition is fully updated and revised to include detailed directions on using both versions of the microcontroller; with no-nonsense recommendations on which is better served in different situations. **\$29.95**



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As see in this issue on page 43.

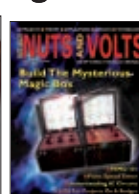
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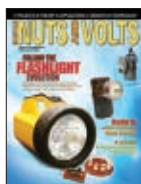
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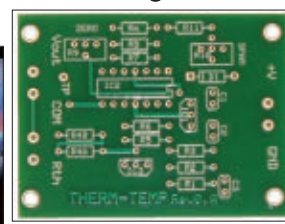
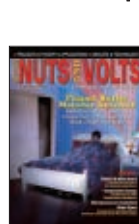
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As seen on the
February 2008
cover

Temperature Gauge PCB



From Jim Stewart's article
"Temperature Gauge Project"

Use this board to build a temperature gauge that ranges from 0°C to 50°C using a thermistor in an analog circuit.

Why use a thermistor? Two words: temperature transducers.

**For more information, please check
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Nixie Clock Kit



October 2006

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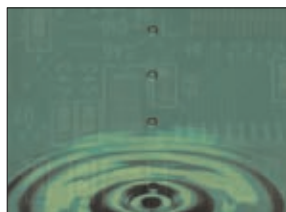
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Freeze Fountain Kit



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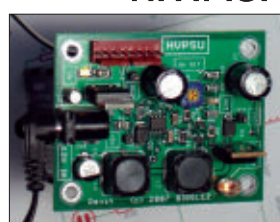
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Publish Date: October 23, 2006

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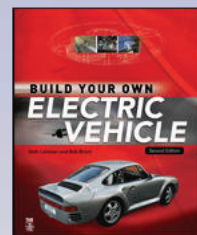
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Solar Power Your Home For Dummies

by Rik DeGunter
Publish Date: Dec 2007

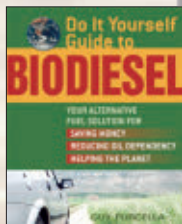
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Do It Yourself Guide to Biodiesel

by Guy Purcella

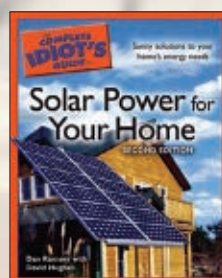
Contains the most current and complete information available for would-be biodiesel makers. This book offers a step-by-step path from the initial desire to do something good for the environment to the final stage of filling the tank with low-cost fuel. Readers are given a complete understanding of what biodiesel is and how to make it properly and safely. There is even a section on pitfalls to avoid, as well as the author's personal tips and tricks. **\$15.95**



The Complete Idiot's Guide to Solar Power for Your Home

by Dan Ramsey / David Hughes
Publish Date: May 2007

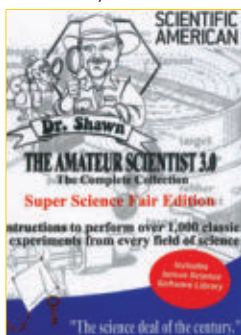
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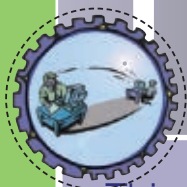
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All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

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- ③ Problem Solving
- ④ Other Similar Topics

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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Accessing Serial Ports With VB

I am using MSComm32.ocx in an MS ACCESS application, using VBA. I need to send and transmit data with this control. I have the mscomm32.ocx file installed on my PC, but I have never transmitted data over a serial port before this project. Please help.

#11081

Vince Finato
Sunnyvale, CA

Air/Fuel Ratio Gauge

I have an air/fuel ratio gauge installed in my car. My understanding of the oxygen sensor is that it has a high impedance output that ranges from zero to one volt. The output varies rapidly through its range, making the gauge dizzying to look at. Does anyone have an idea for a circuit that I could install between the oxygen sensor and the gauge that would "average out" or slow the response of the signal to the gauge? Perhaps a voltage follower with a capacitor on the output?

#11082

Chris Karnow
Hopewell Junction, NY

Power For Hughes Satellite Dish

I was given an HN7000S dish and modem.

The DC in is an eight-pin DIN but I do not have the power supply or pinout to make it myself.

I know I need to have Hughes set it

up and pay them for service but I'd like to have it ready — help!

#11083

Tom Marrapode
Laporte, IN

Guitar Tuner

I am designing a microcontroller-based guitar tuner. However, I am lacking some vital information: What are the frequencies of the open strings (in Hertz)? This would seem like a simple question, but so far I've been unable to locate this information.

#11084

James Burrell
Trinity, AL

Using A PC Power Supply As A Stand-Alone Supply

I would like to use a spare PC power supply as a stand-alone source for the 5V and 12V it provides. What is the simplest way to provide the 5V feedback for a power good signal? Is it possible to use the PG signal to also act as a power on light, as well?

Any sources of part numbers would be appreciated.

#11085

Wes K Miller
Dillsburg, PA

Well Pump Alarm

I volunteer my services to our local water department (which is all volunteer except for our Water Operator). We have three well sites whose pumps are located at the well head. These pumps are connected to variable frequency drives within the

pump stations. I would like to send alarm signals back from the well heads to the pump station over these wires. Is this possible?

#11086

Howard Epstein
via email

Hacking The Kasey Kinderbot

At the local thrift store, I recently picked up a Kasey Kinderbot educational robot made by Fisher-Price. I thought it might be fun to highjack the controls and run my own programs on the robot. Does anyone know the way to do this? I also picked up one of the Rumble Robots (Bolt Man) and found the schematic at howstuffworks.com but they did not include the bar code pattern for the power cards nor the IR control pattern for the manual controls. Has anyone decoded these yet?

#11087

William J. Black
via email

Parallel Port

How does the parallel transfer of data work? Does data flow out from the computer alone, or can data be read into the computer from the parallel port?

#11088

Lynsay Harrison

>>> ANSWERS

Belfast

[#9081 - September 2008]

I live two miles south of the US border. My TracPhone only works reliably about 3/4 miles south of the border.

Can I rig some kind of reflector/antenna/booster amp to improve the range of my phone?

Modern cell phones are digital devices that dynamically adjust the amount of power they transmit via communications with the cell tower. If you are close to the tower, transmit power can be reduced to enhance battery life. On the receive side, next time you see a cell tower, take a look at it. Notice that there are three or more faces to the antenna structure for directional elements. I would suspect that the cell tower you are connecting to might not have any

element points across the border. If you have no billing jurisdiction, why provide services? The other cell service providers in the other country want to make a profit too. Also, on the inter-country issue, consider researching a carrier that offers service in both countries. AT&T comes to mind for their funny commercials about lack of service in different areas. Consider looking into a cell booster or repeater rather than trying to build your own. If you build your own amp that was too noisy, someone would be knocking on your door in somewhat short order. I Googled "cell phone repeater" and got many different websites for both vehicle and home repeaters that should fit your needs.

Tom Homan
Globe, AZ

[#9082 - September 2008]

How do manufacturers specify parameters of passive components?

One example is a 1A diode. Is 1A the maximum current allowed, or is the diode guaranteed to pass 1A continuously? Another example is a resistor. When you use a resistor as a 20 mA current limit to an LED powered by 13.8V, isn't a 1/4W resistor pushed over the limit?

#1 All electronic components have a manufacturer's datasheet, most of which are of standard format and available freely from the manufacturer's website. Exceptions are old parts that were never updated for web access, or proprietary custom parts.

A well written datasheet will tell you everything about the component's performance and operation, and should comply with the standard IEC 60134 Rating Systems for Electronic Tubes and Valves and Analogous Semiconductor Devices. (It dates back to 1964, but is kept current.)

Here is a datasheet for a common "one amp rectifier diode:" <http://tinyurl.com/5dyeqj>. The device is rated to one amp, meaning it can carry that current without failure indefinitely. The same diode can withstand a 30 amp overload for a limited time, as defined by the test criteria in the datasheet.

Most datasheets are written with "Abs Max" and "Typ" sections. Absolute Maximums should never be exceeded as it will likely damage the part, and Typical specs show what the part was designed to do. Some parts are graded by factory testing (such as the PIV of the diode example) and higher voltage breakdown versions would be suitable for more stressful applications. The datasheet also includes testing criteria and mechanical packaging dimensions.

Always design for Typ, test your design for the worse case, and never cross over an Abs Max spec under any conditions.

An LED ballast resistor is easily calculated using Ohm's law. When relatively low supply voltages are used (below 20V), the LED forward voltage drop should be taken into account. Red and green LEDs are 2V or less; blue and white may be as high as 4V. Use the actual part's datasheet to determine Typ voltage drop and Abs Max forward current to prevent damage to the LED.

$$\text{Resistor value needed} = (V_{\text{supply}} - V_{\text{fwd}}) / \text{Desired LED current}$$

So, for a 13.8V supply, 1.8V red LED operating at 20 mA, the resistor would be 600 ohms; a 680 ohm 5% would be safer and not affect the brightness much (if at all). That resistor must dissipate some power, which can be calculated easily:

$$P(\text{res}) = I(\text{led}) * I(\text{led}) * R(\text{ohms})$$

For the above example, the 600 ohm resistor dissipates 240 mW; the 680 ohm dissipates 211 mW (because the LED now runs from only 17.6 mA).

If you have purchased LED "Lamps" that burn out quickly, check the actual voltage being used; 13.8V is a common automotive battery voltage (while charging), and could be much higher if the charging circuit is defective. Either way, the LED lamp could be operated at, say, 90% of the Typ current used now to get you a bigger safety margin. Use the formulae above to calculate an extra series resistor based on the LED



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57BYGH207	NEMA 23	8kg.cm/111oz.in	\$21.50
57BYGH303	NEMA 23	15kg.cm/208oz.in	\$25.95
57BYGH405	NEMA 23	20kg.cm/277oz.in	\$28.90
85BYGH450B-03	NEMA 34	48kg.in/665oz.in	\$68.00
85BYGH450C-03	NEMA 34	63kg.cm/874oz.in	\$89.00

Part #:	Dim:	MicroStep:	Price:
XCW220	100 x 61 x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	\$39.95
CW230	115 x 72 x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	\$48.50
CW250	140 x 94 x 45mm	1(200), 1/2(400), 1/8(1600)	\$54.90
CW860	147 x 97 x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 1/128(25600), 1/512(100000), 1/125(25000), 1/250(50000)	\$96.00

Mini RF Transmitter, Receiver & Transceivers

Ideal for setting up short range wireless links for remote control or data acquisition!

•Transmitter Module w/Power Amplify

- Operating supply voltage: 5-12V
- Frequency: **418MHz**
- Frequency tolerance: $\pm 300\text{KHz}$
- Modulation: ASK/OOK
- Controlled by SAW device
- Antenna included



Only \$9.95!

Item #
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•Receiver Module

- Operating supply voltage: 5V
- Frequency: **418MHz**
- Sensitivity: -102dBm
- Band wide: 3.0MHz (-3dB)



Only \$15.95!

Item #
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•Programmable Transceiver

- Operating supply voltage: 1.8-3.6V
- Frequency range: **300-928MHz**
- Data rate: 1.2-500kbps
- Output power: -30 to +10dBm
- Programmable via SPI
- Antenna included



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Item #
CC1100B

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A Super Value for a Bench Top DMM. Loaded with features and specifications of higher end units, at a very modest price.

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- ACV 700V in 5 ranges
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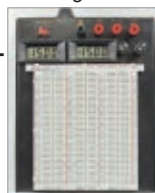
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PBB-272A Powered Breadboard w/ LCD Voltage Displays

Provides the user with a quick and efficient system for breadboarding electronic circuits. Comes with three regulated power supplies along with a deluxe, easy-to-use breadboard. **Two LCD's conveniently show the 0-15 positive and 0-15 negative outputs.**

- 5 Distribution Strips (500 tie points)
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- One Ground
- One 5VDC (1 AMP) Constant Power
- One 0 to +15VDC (500mA) Variable Power
- One 0 to -15VDC (500mA) Variable Power
- 110VAC Input Power, $\pm 10\%$



Item #
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High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life. All 3 Models have a **1A/5VDC Fixed Output** on the rear panel.



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CSI5003X5 0-50V/0-3A	\$127.00	\$119.00
CSI3005X5 0-30V/0-5A	\$129.00	\$122.00

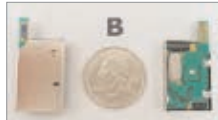
•Shielded Transceivers

- DATA in RF out
- RF in DATA out
- Data rate: 1.2 to 10kbps
- Output power: +10dBm
- Sensitivity: -108dBm
- Operating supply voltage: 5V
- Frequency: **915MHz or 2.4GHz**
- Antenna included



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Item # **EZ915 (A) 915MHz**
and
Item # **EZ2400 (B) 2.4GHz**



Soldering Station w/Ceramic Element & Separate Solder Stand

- Ceramic heating element for more accurate temp control
- Temp control knob in F(392° to 896°) & C(200° to 489°)
- 3-prong grounded power cord/static safe tip
- Separate heavy duty iron stand
- Replaceable iron/easy disconnect
- Extra tips etc. shown at web site



Item #
CSI-STATION1A

\$39.95!

Also Available w/Digital Display & MicroProcessor Controller

Item #
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SALE!
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ESD Safe CPU Controlled SMD Hot Air Rework Station

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SALE!
\$129.00

Item#
CSI825A++

Our Premium All in One Repairing System

- Combines the function of a Hot Air Gun, Soldering Iron and a Desoldering Gun.
- Microprocessor controlled ESD safe unit with all digital display
- Desoldering tool comes with zero crossing circuitry preventing electrical surges and equipped with air cylinder type strong suction vacuum pump.
- The 24V soldering iron is compatible with the compound tip design.
- Uses lead-free or standard solder.



SALE!
\$199.00

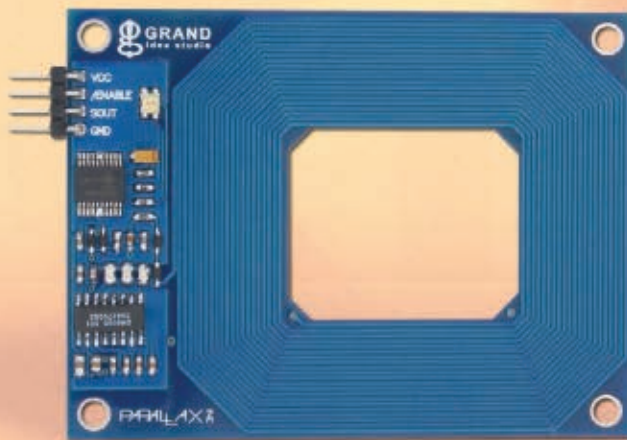
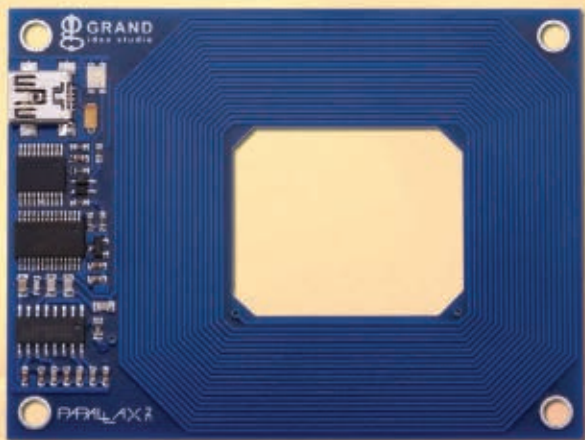
Item#
CSI-9000

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1 fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA



Item #:	Price 1-4	Price 5+
CSI3003X3 0-30Vx2@3A	\$198.00	\$193.00
CSI3005XIII 0-30Vx2@5A	\$259.00	\$244.00



RFID READER MODULES

Designed in cooperation with Grand Idea Studio, our (RIFD) Reader Modules are convenient low-cost solutions to read EM 4100 low-frequency (125 kHz) passive RFID transponder tags. The RFID Reader Modules can be used in a wide variety of hobbyist and commercial applications, including access control, automatic identification, robotics, navigation, inventory tracking, payment systems, and car immobilization. Board dimensions are 3.25 x 2.45 in (8.25 x 6.22 cm).

New! RFID Reader Module - USB (#28340; \$49.99) - This module connects directly to a USB port both for power and to output transponder tag data to your custom PC application. A sample Visual Basic (VB.net) application is provided on the 28340 product page. *Features include:*

- Built-in USB interface for easy connection to your PC
- 2400 baud serial output stream to PC is accessible from any programming language that can open a COM port
- Transponder tag ID data given as a 12-byte ASCII string
- Bi-color LED for visual indication of activity
- Power required: 5 V (USB connection); 10 mA idle, 90 mA active

Note: a USB A to Mini-B cable is required, sold separately (#805-00006; \$6.99). Several transponder tag styles are available from Parallax, www.parallax.com.

Best Seller! RFID Reader Module - Serial (#28140; \$39.99) - This 4-pin module is designed for easy prototyping and integration into stand-alone microcontroller-based applications. Parallax provides sample code in PBASIC and SX/B on the 28140 product page. *Features include:*

- 4-pin 0.1 inch SIP header for power, ground, enable, and data-out connections
- 2400 baud TTL serial output (81N) to any Parallax microcontroller
- Transponder tag ID data given as a 12-byte ASCII string
- Bi-color LED for visual indication of activity
- Power required: 5 VDC; 10 mA idle, 90 mA active

We also offer the RFID Reader Modules as part of sampler kits which include an assortment of four RFID transponder tags.

RFID Reader (USB) and Tag Sampler Kit (#32395; \$55.99; right)

RFID Reader (Serial) and Tag Sampler Kit (#32390; \$45.99)



Order **RFID Reader Modules** at parallax.com or call our Sales Department toll-free at 888-512-1024 (Monday-Friday, 7 a.m. - 5 p.m., PT).

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